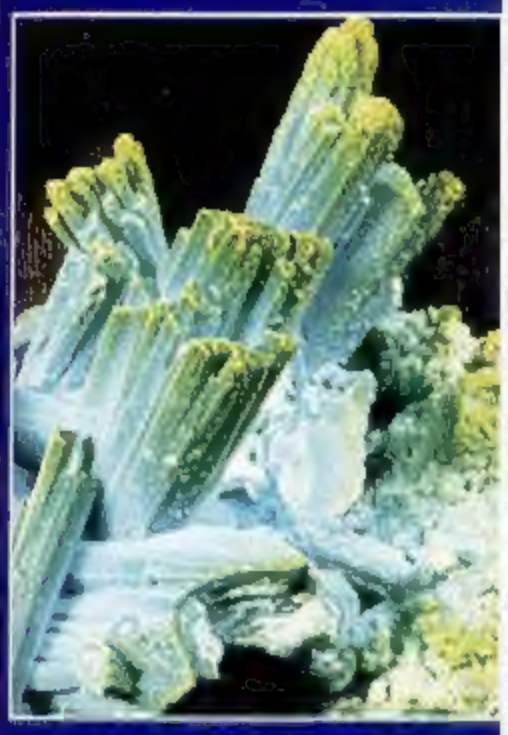
FEBRUARY 2007

Rock&Gem

THE EARTH'S TREASURES • MINERALS AND JEWELRY

EARTH'S AMAZING MINERALS

SILVER TREASURES



SILICATES: Fine Forms

FORCES OF NATURE

GOLD IN THE 21ST CENTURY

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Rock&Gem

Volume 37, Number 2 February 2007

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ON THE COVER

Gemmy crystals of tanzanite, a variety of the silica mineral zoisite, are popular in jewelry. (Jeff Scovil photo/Barker & Co. specimen)

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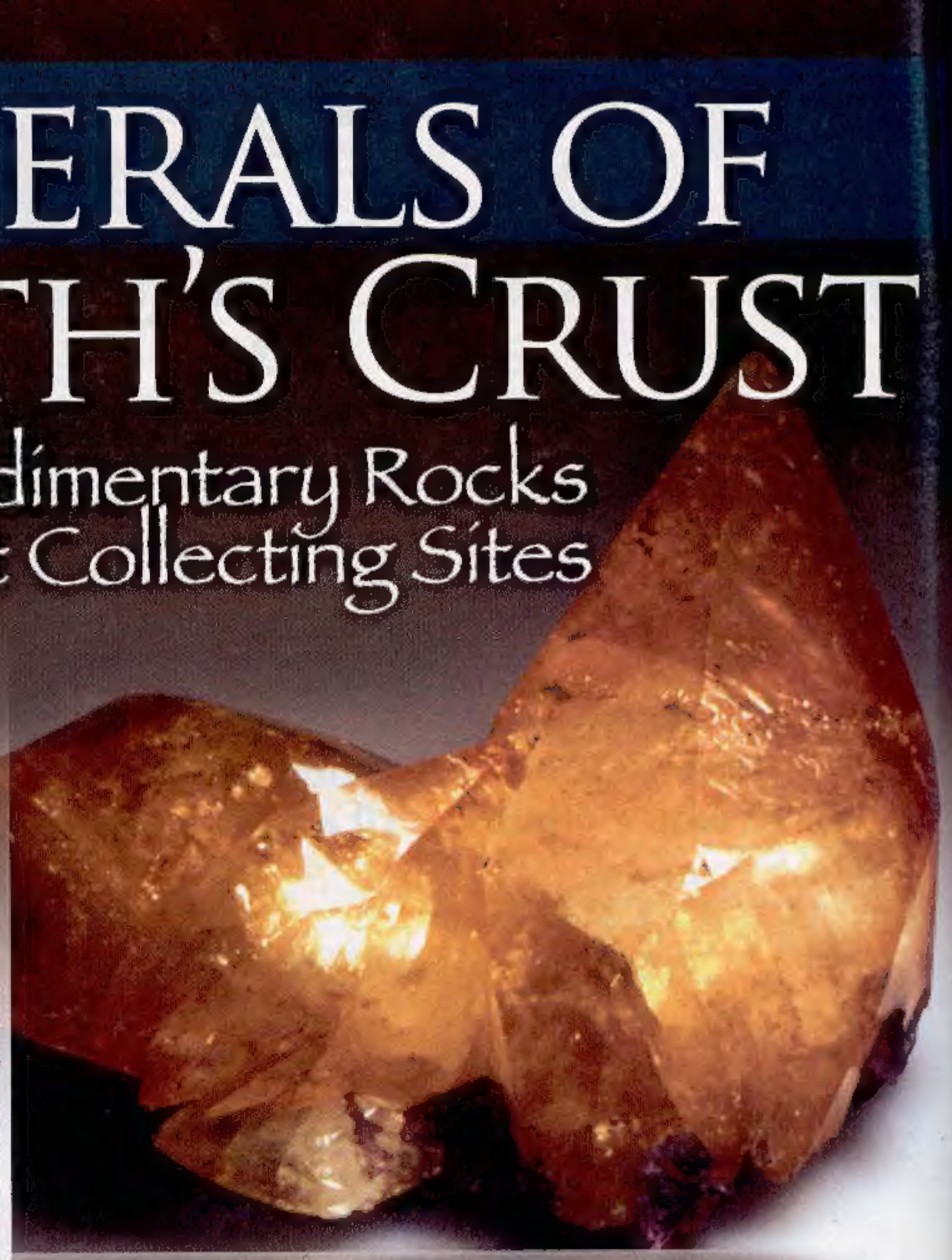
Minerals of Earth's Crust

Part II: Sedimentary Rocks Are Great Collecting Sites

Story and Photos
by Bob Jones

Editor's Note: Part I of this series ran in the November 2006 issue of *Rock & Gem.*



The lead, zinc deposits in the limestone of Elwood, Tennessee, are world famous for superb, honey-colored calcites.

As Earth's crust was forming, it was being attacked simultaneously by the forces of nature: wind, rain, ice, snow, running water, even volcanoes and earthquakes. All these forces are still attacking all crustal rocks—metamorphic, igneous, and even previously formed sedimentary rocks, which owe their existence to early forces of weathering. With its ability to dissolve almost anything, water attacks any rocks it contacts, whether slowly or rapidly.

Rainwater uses the atmosphere as an ally. The atmosphere provides carbon dioxide to turn rainwater into a very mild acid. As air pollution increases, so, too, does the acidity of rainwater. We are well aware of the effects of acid rain on statues, lake water, marble buildings, and Earth's rocks.

Surface water also dissolves organics as it flows over the land. Rotting plant matter enhances water's ability to dissolve things. Even frozen water can attack surface rocks from inside every crack and seam of the formation. Freezing water expands, exerting pressure on the rock and causing it to crack.

Rocks immediately begin to break down, or decompose, when exposed to and attacked by the forces of nature. This releases the minerals in the rocks in both solid and liquid form. Water seems to have an affinity for iron and calcium minerals. These are the basic ingredients of "hard" water.

Other minerals, when attacked by water, release grains, fragments, molecules, and even atoms, which are carried away in solutions. Wind, running water, and ice carry these fragments and deposit them as sediments. The rock fragments become sand and mud, eventually becoming the sedimentary rocks sandstone, limestone, conglomerate, shale, and the like.

Weathering of Earth's rocks has been going on since the birth of the planet. Some of our most remarkable deposits—like the huge iron ore deposits of the Mesabi and Vermillion ranges of Minnesota—started out as the minerals in igneous rocks, which were subjected to weathering over 500 million years ago!

Sedimentary rocks form on land or on the floors of oceans and other bodies of water. Eventually, the products of weathering end up as solid sediments either on dry land or at the bottoms of rivers, lakes, ponds or oceans.

One significant part of the process that creates sedimentary rocks from the land's gravels, sands and muds is the cementing agents that help convert sediments into solid rock. As water seeps through loose sediments, it brings along dissolved minerals. When deposited, these minerals act as a glue to hold the particles of rock together. Among the important cementing agents are iron oxide, manganese oxide, calcium carbonate, and most important, silica.

The numerous crystallized quartz specimens from Arkansas are found in a group of sandstone deposits.

Geodes and septarian nodules like this one with calcite crystals are often found in sedimentary rocks.

Other factors are gravity and weight. As sediments pile higher and deeper, the huge pressures exerted by overlying sediments help compact and solidify the earlier-buried sediments.

Once formed, sedimentary rocks are subject to ground movement, frost, and heat expansion. These forces create cracks and avenues through which later solutions containing dissolved minerals, most commonly silica and calcium carbonate, can enter the rock. The solutions contribute to the growth of crystals and crystalline material in openings in the rocks.

Of the common cementing agents, iron oxide gives many sedimentary rocks their lovely red to orange to pink colors. Virtually every beautiful sedimentary rock formation we can name in the West—Monument Valley, Echo Cliffs, Garden of the Gods, Grand Canyon, Bryce Canyon, Painted Desert—owes its lovely colors to iron oxide, either as a cementing agent or a surface stain. Sometimes, as in the Painted Desert, manganese oxide is a significant contributor to the beauty of the landscape.

Silica is the toughest of cementing agents, as any rockhound who ever worked a quartz pocket will tell you. Where quartz crystals have formed, the cementing agent is most likely silica, and you would be hard pressed to get that crystal group out without any damage!

There are some marvelous collecting sites in the United States whose sedimentary rocks are rich in quartz crystals. One of the better known deposits is the area around Hot Springs, Arkansas. An equally prolific, but entirely different, well-known deposit is in the vicinity of Herkimer and Middleville, New York. The Hot Springs-area rocks are pure sandstone, full of veins and pockets of stunning quartz crystal groups. The rocks in the Middleville-Herkimer area are of calcareous sandstone. This indicates the cementing agent is a calcium carbonate, but if you have dug there, you know those rocks are no less difficult to break than rocks cemented by silica.

The Arkansas quartz crystals occur in veins running through the Blakely and Crystal mountains. Openings in the veins may hold crystals well over 6 inches long in diverging cluster plates that can exceed several feet across. The crystals are brilliant, water clear in the upper portion of each crystal, and usually milky at the crystal base.

The Arkansas quartz deposits are so extensive that they have been mined commercially for decades. Individual collecting is allowed at a number of sites around Hot Springs for a fee.

The New York quartz deposits differ from Arkansas' in several ways. The most obvious difference is the circumstance in which crystals are found. Arkansas quartz occurs on a sandstone matrix, attached at the base so that each crystal shows only one termination. The Herkimer and Middleville crystals almost never occur attached to matrix, but have developed in open cavities.

Virtually all the crystals found in the New York area are doubly terminated, either penetrating other quartz crystals or loose in small pockets in the rock. Their brilliant luster, gemminess, perfect hexagonal shape, and double termination have earned these quartz gems the name "Herkimer diamonds."

The Herkimer crystals seldom exceed an inch or more, but a few have reached several inches in length. The larger crystals often show imperfections, gas bubbles, incompletely developed faces, and inclusions. They may also show internal cracks from frost damage. The main inclusion in these crystals is a black carbonaceous mineral, as well as gas bubbles and liquid inclusions.

One of the trends lately seen in Herkimer quartz displays is the reconstruction of crystal clusters. When crystals formed in some pockets, they grew in contact with each other, though perhaps not actually attached or with such a weak attachment that the crystals did not stay in touch. When the pocket was opened, the crystals were no longer attached to each other. Collectors who carefully remove the crystals can use the points of interference as a guide to reassembling the cluster into a very attractive, gemmy display piece.

At other collecting sites, small doubly terminated quartzes have weathered out of their original sedimentary rock. Names like "Cape May diamonds" and "Pecos diamonds" reflect where they were found. In Arizona, we have "Diamond Point" near Payson, where single quartzes developed in the limestone.

Shale is another common sedimentary rock. It is often layered with sandstone, since sand and mud have a common source. As the water carrying sediments slows, the heavier particles settle out first, forming gravel deposits. Next, sand and mud are deposited. Dissolved minerals settle on top of the others. The gravels, when cemented, become conglomerate, a mixture of rounded pebbles and sand. Sands are converted to sandstone, and the mud becomes shale. The dissolved minerals form layers of more- or less-useful minerals like borax, gypsum and halite.

continued on next page

Shale seldom produces noteworthy collector crystal specimens, but it is often the source of interesting fossils of previous life. Since mud is fine-grained, it compacts and cements easily. Such fine material does a good job of creating imprints and filling open spaces to replace or mimic the hard remains of early life. We find the remains of pelecypods, snails and bi-valves of various sorts in shales.

If the shale is particularly rich in sulfur and iron, animal remains may be replaced by iron sulfide, which can form either pyrite or marcasite. Such fossils are more highly prized because of their attractive color, metallic luster, and hardness. They are found in some areas of Ohio, Germany and Siberia.

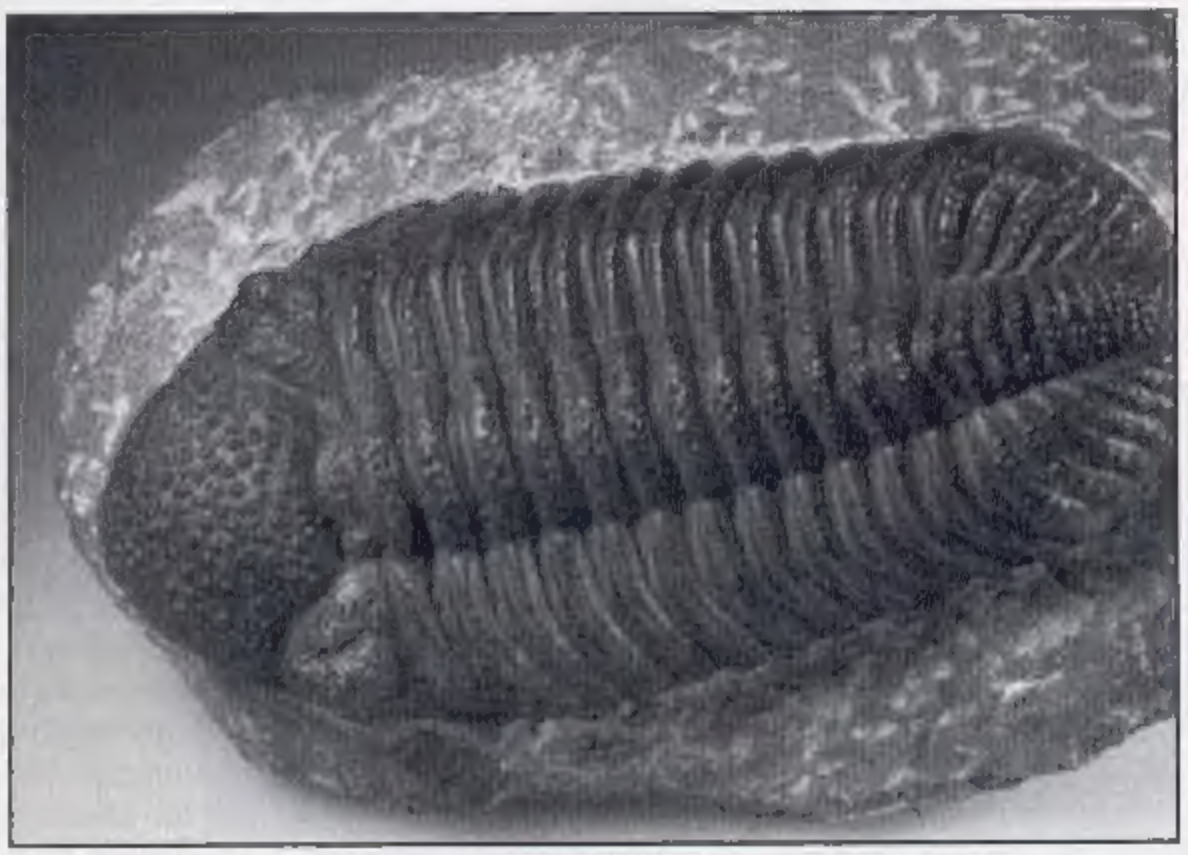
With enough heat and pressure, shale converts (metamorphoses) to slate or, if the forces are even more intense, phyllite. Slate can contain several different mineral species, which form from the available ingredients in the shale as it is metamorphoses. The more common of these is pyrite, usually occurring as simple cubes, though pyrite suns—disc-shaped, radiating crystal groups—are common in some formations.

Another major group of sedimentary rocks that forms on land develops when water loaded with dissolved minerals collects in low areas. The water slowly precipitates its mineral load as it evaporates. This is especially true in hot, desert places where the water has no outlet. Solar heat accelerates evaporation, which accelerates precipitation. As more water flows into this "dry lake" area, more dissolved minerals are added to the deposit. This cycle of inflowing, evaporation and precipitation results in mineral species called evaporites.

The most common evaporites are halides like halite and sylvite, gypsum, some borates, celestine, other sulfates, and some of the useful zeolites, like phillipsite. Dry-lake deposits are rich sources of minerals that chemical and pharmaceutical companies convert into useful products.

One of the larger sources of evaporites is the Great Salt Lake in Utah. An ancient sea became trapped as the land rose, creating Lake Bonneville, whose shorelines can still be seen on the slopes around Salt Lake City. Water flowing off the slopes supplemented the trapped lake as the seawater evaporated. The remaining water grew richer in dissolved minerals. As dry land emerged, the Bonneville Salt Flats were created. The remaining water, now called the Great Salt Lake, is rich in dissolved evaporates, which can be extracted and used in industry and commerce. Keep in mind that seawater tends to be quite rich in sodium and chlorine, usually in the form of halite salt, and radicals of sulfur and carbonates.

Evaporite minerals are also deposited in dry lakes in California. Probably the most noteworthy of California's dry lake regions is the Mojave Desert's famous borax deposits. The boron found there resulted from earlier volcanic action in the nearby mountains. It was absorbed by rainwater and carried to a huge, landlocked basin, where a variety of borate species formed as evaporites. The deposit was so rich it was developed into the most important source of boron in America. Its deep layers of mineral contain kernite, colemanite, borax, and a variety of other useful borate minerals.



Midwest limestone is a good source of trilobites, a prehistoric life form.

One interesting calcium, sodium borate mineral from Boron is ulexite. It was originally found as white, needlelike tufts scattered over the desert floor in and around Death Valley. Prospectors learned to test these white tufts in an open flame. If the flame burned pale green, the mineral contained boron. Claims were staked all over Death Valley and the Mojave Desert, and serious mining commenced. The old mine properties in Death Valley are still interesting sites, though collecting there is prohibited.

The biggest Death Valley boron deposit is well known from its symbol of 20 mules pulling an ore wagon across the open desert. The main ingredient of 20 Mule Team Borax® was once mined in Death Valley and around the town that owes its existence to the boron deposit it sits on. The deposit around Boron was developed first as an underground mine, the Baker. A huge open pit eventually evolved and is still producing.

I was lucky enough to be taken underground at the old Baker Mine, now part of the big open pit at Boron. Our goal was to search these old workings for sump holes in which groundwater, rich in borax, would accumulate and precipitate out crystals. The underground workings, now closed, were so huge that we drove deep underground in a truck. After walking a long way from where we parked, we found tunnels where side trenches guided water into several sump holes. These sumps were so rich in borates they were completely lined with 1- and 2-inch borax crystals in tight clusters. We were able to collect nearly two dozen flats of these colorless minerals in fairly short time. Of course, sticking your bare arm into a saline water-filled sump hole is a real treat, especially if you have scratches and scrapes. But the stinging was worth it!

Borax crystals are transparent and colorless with sharp monoclinic form. The borax molecule holds eight molecules of water, which immediately begin to escape the structure when the mineral hits dry air. As borax loses water, over a period of days or weeks, it alters to a new mineral, tincalconite. Tincalconite is a very light, quite soft mineral that is easily crumbled if handled. Therefore, fine specimens don't last unless sealed away from atmospheric changes.

Another dry lake often visited by collectors—with permission—is Searles Lake, north of Boron. The lake's water is richly saline and crusted over with mostly halite. By breaking a hole in the crust, you can reach into that water and feel under the crust for crystals, which are abundant. Halite crystals often have a pleasing pink color caused by salt-resistant algae that only grow in Searles Lake and one other lake in Germany!

The mud around the perimeters of some of these lakes will also yield collector minerals like blödite and hanksite. Many evaporite minerals have to be

oiled to prevent them drying out.

The first of granite's minerals to be attacked by weathering is feldspar. Decomposing feldspar forms clay, which is carried away by flowing water to become mud, which settles and changes to a rock we call shale. As the feldspar in granite breaks down, other minerals, including flakes of mica, biotite or muscovite, and quartz, are released. The micas tend to become part of the mud.

When the feldspar in granite slowly softens and turns to mud, the weather-resistant quartz grains in the granite break free. These quartz grains are carried away by running water and accumulate as beach sands, desert sands, or part of a sand and gravel mixture dumped by streams and rivers to form deltas.

In unusual cases, granitic rocks are rich in a particular iron-magnesium mineral, like olivine, or magnetite or rutile, another metal compound. These minerals also become sediments and may create sands that are rich enough for the mineral to be mined from them. If you have ever visited the Hawaiian Islands, you may have walked the black or green sand beaches. The black sand is formed from grains of lava, while the green sands are crystalline bits of green olivine, a common mineral in lava. Because the lavas of Hawaii cool rapidly, few mineral crystals of any size can form, so collecting there is very limited.

While a variety of sedimentary rocks form on land or in shallow water, another sedimentary rock type, limestone, is slowly forming in the oceans. When pure, limestone is calcium carbonate. We call it calcite or aragonite, depending on its crystal structure. A similar material found in seawater is magnesium carbonate, which we call dolomite. It can form in the same way as calcium carbonate limestone and is often mixed with it.

Most oceanic limestone results from two processes: the action of sea life and the precipitation of inorganic calcium carbonate. A considerable variety of sea life, particularly tiny creatures, absorbs the calcium in water and combines it with carbon dioxide to form calcium carbonate. When the organisms die, their remains eventually fall to the ocean floor. Scientists estimate that it takes an average of 10,000 years for a 1-inch layer of calcium carbonate to accumulate on the ocean floor!

Of course, the limey accumulation on the ocean floor is not pure calcium carbonate. It also contains magnesium carbonate, a variety of mud types, the silica remains of diatoms, organic matter from fish, and anything else that settles to the ocean floor. Almost all limestone is impure, some much more than others.

One of the oddest accumulations of sediments is happening in the Black Sea. The sea is so deep that oxygen is virtually absent from its deepest waters. The water is rich in various dissolved metals and in sulfur. If oxygen were present, these metal salts would oxidize, but without oxygen they combine with sulfur, so that pyrite, chalcopyrite, and other sulfide minerals forming in the Black Sea's bottom mud!

The precious opal deposits in Australia are composed of a form of silica called cristobalite, which tends to form spherules as it crystallizes. The region was a shallow sea millions of years ago. As sediments settled out, siliceous ash from nearby volcanic action became part of the sediments. Water defitrified the silica fragments in the ash and carried them deep into the sediments, where they accumulated in very quiet surroundings. Gradually, the cristobalite settled in orderly, more or less parallel layers. Opal miners work diligently to find these pieces of crystallized silica. When exposed to light, their orderly spherule arrangements diffract the light into the fiery colors of precious opal.

During the development of limestone deposits, if circumstances permit, concretions and geodes can form. These occur when various molecules migrate toward each other and attach. Thus, we find such minerals as pyrite, calcite, gypsum, barite, and even fine opal developing.

Cases in point are several places the Warsaw limestone formation outcrops, such as the Keokuk, Iowa, and St. Francisville, Missouri, areas. This famous limestone formation yields wonderful quartz geodes that range from under a pound to over 50 pounds. The geodes are quartz "shells" lined with superb quartz crystals, which host choice calcite crystals and micro-sulfide minerals. The silica for these geodes often came from the silica impurities in the limestone.

On one collecting trip to St. Francisville, I was able to collect dozens of geodes, including a 50-pounder lined with quartz points on which sat several wonderful calcite crystals.

Of all the sedimentary rocks, limestone is the most fruitful source of collector specimens, particularly because of the variety of species found in it. Limestone can offer a wonderful variety of crystallized species including calcite, quartz, celestite, pyrite, fluorite, gypsum, dolomite, strontianite, agate, quartz geodes, and sometimes calcite or barite concretions. Add fossils to this list, and you have fruitful hunting grounds.

continued on next page

Minerals of Earth's Crust *from page 15*

The Warsaw limestone formation is one result of an ancient sea that once covered the middle of the North American continet. Many a Midwestern road cut shows layer after layer of limestone, along with layers of shale.

Weathering has attacked this Midwest limestone, creating cavities and open seams and dissolving out huge caverns, some of which actually served as mineral sources at one time. Mammoth Cave in Kentucky was worked for its saltpeter (potassium nitrate) during the Civil War. Mineral-rich solutions trickled into these openings and gave rise to a variety of minerals. The minerals formed at or near ambient temperatures, developing slowly.

In rare cases, limestone is snow-white and virtually pure. We call limestone that has been metamorphosed marble. If the limestone was quite pure, the marble is white. If the limestone was loaded with impurities, the marble can exhibit colorful patterns that add beauty to its function. One of the great sources of white marble in Europe is at Carrara, Italy, just north of Pisa.

Limestone is the key ingredient in cement. The quarried rock is crushed to powder and heated to drive off impurities. Gypsum, which readily absorbs moisture, is added. The mixture is heated, then bagged. When water, sand and gravel are added to it, a chemical reaction begins. As moisture is lost, the mixture hardens and forms concrete, one of the most important building materials ever developed.

Limestone can also be heated to release the carbonate radical, leaving behind calcium oxide, which we call lime. This material has vast agricultural uses in treating acid soils.

Limestone quarries in the Midwest have been a never-ending source of fine collector minerals. The famous quarry at Clay Center, Ohio, produced distinctive amber-colored fluorite cubes that fluoresce beautifully because of included bitumen. Often, these cubes are pierced by snow-white celestites in lathelike blades to several inches long.

Fluorite, calcite and celestite, along with lesser occurrences of pyrite and barite, are the premier collector minerals in Midwest limestone quarries. A variety of fossils, some of them pyritized, also developed in the limestone, adding to the excitement of collecting sites.

While still under the sea, limestone can develop faults, cracks, dissolution cavities, and caverns. Once the limestone is exposed as dry land, these cracks, faults and openings become avenues and sites for the development of mineral crystals via weathering. Crystals, particularly calcite, are common in Midwest limestone.

A quarry at North Vernon, in Jennings County, Indiana, has produced quite remarkable honey-colored calcites, many of them twinned. They are highly modified, which gives them an almost spherical shape.

Celestite is a very common mineral species in some sedimentary limestone formations.

Most Midwestern limestone collecting sites produce nonmetallic species of no ore value, but valuable quantities of useful metal ores have been found in a few deposits. These rare sites have won over the hearts of collectors with wonderful sulfide and gangue minerals.

When hydrothermal solutions invade limestone and deposit ore minerals like galena and sphalerite, they can further dissolve the limestone to enlarge openings. Calcite and fluorite, sometimes in marvelous crystals, are among the gangue minerals usually deposited in Midwestern limestone. In the fluorite deposits of southern Illinois, where the fluorite is an ore and not a gangue mineral, uncommon and even rare minerals are found, including strontianite and witherite.

The Tri-State area around Joplin, Missouri, was one of the great limestone sources of zinc and lead ore, as well as collector specimens. Calcite, sphalerite, galena, marcasite and chalcopyrite crystals were common here. The Viburnum Trend region of Missouri is still operating. It has produced marvelous calcites, many of them yellow, with others showing sharp phantom outlines of micro-sulfide crystals, including chalcopyrite. The area's mines have also produced amazing, brilliant, razor-sharp galenas.

More recently, the amazing limestone deposit at Elmwood, Tennessee, has produced a suite of ore and gangue minerals that are highly prized. Most spectacular are the marvelous, honey-colored, scalenohedral calcites of very large size. These are often found with and on resinous masses of sphalerite crystals. Often, snow-white, radiating, spherical groups of barite to several inches across perch on the sphalerite crystal groups.

Remarkable gem fluorites in yellow, violet and reddish hues top off the Elmwood suite. The fluorites are often heavily etched and can be color-zoned and gemmy. Many of the gemmy crystals have been faceted into several-hundred-carat gemstones. While such a deposit is not open to the average collector, miners have brought specimens to market. Now, the company has realized the value of these minerals and has entered into collecting contracts with private specimen diggers who have been very successful in bringing forth superb specimens of the above four minerals.

The fluorite deposits around Cave in Rock and Rosiclare, Illinois, are world famous. Some of these fluorites are quite appealing. The Auglaise Quarry in Ohio produced some fascinating small fluorite cubes that were infused with organic material and show a steely blue to tan rainbow effect.

Lime City, Ohio, is well known for fine brown fluorite cubes. In fact, this calcium fluoride—as well as calcite and celestine—is liable to show up in almost any of the Midwest limestone deposits.

Portage, in Wood County, Ohio, has produced enormous celestine crystals to 15 inches, while a limestone quarry in Sandusky, Ohio, has yielded celestines at least 8 inches long. The celestine from these quarries is generally white, but can be pale blue. Many crystals are thin and very brittle, while others are bladelike and sturdy. Keep in mind there are probably some 10,000 quarries in America, and many of them are limestone quarries in the Midwest.

Shop Talk

William A. Kappele

Torch-Fired Enamel

It is hard to believe that 10 years have passed since I first wrote about torch-fired enameling in this column. At the time, I had never even heard of it. I had just finished writing about enamel bead making and wondered to myself why the torch couldn't be used instead of a kiln for what I had always called "copper enameling," even though enamel has been applied to many other types of metal as well for almost as long as the process itself has been around. I decided to give it a try (on copper) and got acceptable results, so I passed my observations on in the column.

I recently decided to revisit the subject, and by poking around on the Internet, I found that there are bazillions of sites that talk about what is now called "torch-fired enameling." Just as with using a kiln, the idea is to fuse a special type of glass, called enamel, to metal. This can be done on something as simple as a square of thin copper sheet using a single color of enamel or as complicated as a delicate construction of precious metal using myriad enamel colors.

The most common types of enameling are cloisonné, champlèvé, basse-taille and plique-á-jour. In cloisonné, thin strips of metal called cloisons, or partitions, are placed on the surface of the piece to form the design in a pattern of cells. These cells are then filled with enamel until it is slightly higher than the cloison. Then the enamel is ground down until it is flush with the cloisons and is then given either a polished or matte finish.

Champlèvé is formed in one of two ways. One way is to carve or groove the base metal, then fill these depressions with enamel. The other way is to build up the base metal by soldering pieces to it. Again, the resulting grooves are filled with enamel.

Basse-taille is achieved by texturing the base metal by etching, engraving, carving, etc. The entire surface is then covered with a thin layer of translucent enamel that allows the texturing to show through.

Plique-á-jour is also formed in two basic and slightly different ways. In the first method, the pattern is formed much like the cloisons, but without a backing piece. The cells are then filled with enamel and fired. The result is much like a tiny stained glass window. The second method is again, much like cloisonné. The difference is that after several layers of enamel have been applied, the backing is burned away in an acid bath.

No matter which of the above methods you might want to try, you will have to have a way to fire the enamel. The way the big kids do it, of course, is with a kiln, but these fellows can cost as much as a gallon of gas. Perfectly acceptable results for the hobbyist can be achieved with a common propane torch from the hardware store.

The work must be heated from below so that the enamel powder will not be burned or blown away by the torch flame. An easy way to support the piece is to use a ring or beaker stand covered with a small piece of coarse screen to hold the work. There are lots of variations to the process, but this will get you started so that you can decide whether you like it before mortgaging the farm to buy equipment.

Please feel free to contact me if you have a suggestion or comment about this or any of my Shop Talk columns. My e-mail is quappelle@cox.net, or write to me at 25231 Pericia Dr., Mission Viejo, CA 92691.

the FRUGAL COLLECTOR

THE SILICATES

Part VI:
Tanzanite, Chrysoprase, and Gem Silica

Story and Photos by Bob Jones

Last month, I mentioned sugilite, a violet-hued massive lapidary material that took the gem and lapidary world by storm when it appeared a few decades ago. Sugilite was known early on as royal lavulite or royal azul. The first article ever published on this gem appeared in *Rock & Gem*. In that article, I named the mineral "royal lavulite." Once the material was completely identified, it was given its correct mineral name, sugilite. The mineral was first found in Japan as insignificant crystals.

This beautifully colored material is not as complex as charoite. It is primarily a mineral, a fairly complex potassium, sodium, iron, manganese, aluminum lithium silicate. The manganese content causes the color, as it does in charoite. Sugilite also contains a mix of minerals, but only to a minor degree.

The original sugilite is an indistinct mineral found as small, yellow grains in a syenite rock on the Island of Iwagi in the Ehemi Prefecture of Japan. Like charoite, sugilite, which is usually a complex mineral, can also be a mixture of several minerals with sugilite dominating in content and color.

Randy Polk made wonderful jewelry from sugilite, a violet-hued massive lapidary material.

Because the first sugilite found was so nondescript, it made no impression on anyone until it was discovered again in the ancient stratiform manganese deposit known as the Kalahari manganese field centered around Hotazel, North Province, South Africa. Hotazel gets it name for just that reason—it is hot as you know where! The original manganese minerals of this ore body were laid down over 2 billion years ago. Sugilite has also been found with massive rhodonite in New South Wales, Australia, but little is known of this deposit.

The leading African mine is the Wessels Mine, rivaled by the mine at Hotazel and several others. These penetrate a massive layered manganese ore body so vast it supplies the majority of the world's manganese. Found in layered structures within the ore body, Wessels Mine sugilite occurs in quantity as bright violet, rock-like masses suitable for use in carving and jewelry.

My introduction to sugilite came when I had a call from Dave Cordry, a skilled artist, who suggested I visit Randy Polk, an artist who had been featured in *Rock & Gem* several times. Randy and Dave had brought the first significant quantity of sugilite into this country.

At the time, the composition of the material was unknown, so Randy named it "lavulite" for its magnificent violet color. It struck me that the royal purple color of the material deserved an adjective. So the first article ever done on this mineral appeared in *Rock & Gem* calling the lovely violet gemstone "royal lavulite"!

The mineral was finally identified as sugilite. The superb color of this gem is due to a trace of manganese, so it is technically known as manganoan sugilite. That the mineral is rich in manganese should come as no surprise since it is found in the world's largest manganese mineral deposit, generally known as the Black Rock District of the Kalahari Desert.

The deposit extends for 140 kilometers and holds several billion tons of the black mineral group. I say "group" because manganese is found there as a mix of several different manganese oxides. Other manganese minerals found in collector quality here include manganite, hausmannite, pyrolusite, and some of the most attractive rhodochrosite ever found. The Black Rock rhodochrosite forms in scalenohedral or dogtooth crystals, unlike the simple rhombohedrons we associate with the Colorado rhodochrosites.

Once sugilite began to catch on as a gem, the Gemologiocal Institute of America (GIA) did an in-depth study of the mineral. Its findings proved very interesting; they showed the violet gem material was really two different minerals. The opaque massive material is primarily sugilite. The finest translucent, nearly transparent red-violet sugilite, however, was actually gem chalcedony infused with sugilite to give the colorless quartz variety a superb violet hue. This violet gem silica commands the highest values for sugilite.

The massive manganoan sugilite makes excellent carving material. Its hardness (Mohs 6) means it is not too challenging to work. While the color of the massive material can be homogenous, a lot of it shows mottling due to included minerals. The better colored massive sugilite is often used to make fine inlay jewelry, as it contrasts nicely with gemstones of other colors.

The Black Rock chalcedony—actually sugilite silica—has a hardness of about Mohs 7, so it is very suitable as a gem. Its lovely, limpid violet color makes it an ideal addition to the suite of colorful massive gems the lapidary can use. Polk used to refer to the color of this gellike material as "gumdrop" violet.

When colorless chalcedony is infused with nickel salts, it becomes the lovely, limpid green gem chrysoprase.

The violet chalcedony that is nearly transparent can be faceted for ring stones and pendants, while the slightly more dense material makes superb cabochons, beads, and elegant jewelry stones. Often, the finest massive gellike sugilite is used creatively and carved into choice flowing, swirling, freeform designs for brooches, pins, pendants and earring stones by some of America's leading, prize-winning artists.

The Black Rock sugilite occurs in thin to thick more-or-less horizontal layers that may extend 50 feet or more before tapering off. Smaller patches of the material occur in brecciated material encountered during mining. It's interesting to note that this violet material is not easy to identify underground. Manganese mines are notoriously dark, as the minerals are black and the walls seem to completely absorb any light used. Even when well lit, the black manganese ore fails to reflect light, so the sugilite is very difficult to spot. I suspect much of it went to the crusher before someone realized its potential.

Once the value of this gem was realized, the miners were trained to recognize it and save it for sale. It is estimated that some 20 tons of material were initially mined and piled on the surface.

Can you imagine a pile of this gem material weighing tons? What I find really interesting is that this tonnage was not stored under lock and key! Rather, it was simply piled on the ground near the guard shack. It was fenced in and guarded, not by armed personnel, but by a flock of geese that raised an alarm whenever someone came near.

What I find remarkable about sugilite is that in just a few short years it has become a major gemstone, undoubtedly because of its superb violet-blue color. In that regard, it enhances any small assemblage of colored stones. Its supply seems to wax and wane depending on the mineral's occurrence during mining, but since the manganese deposits are so vast and manganese is in high demand for steel making, it seems likely that sporadic finds of good gem rough will continue to occur.

Another gemstone boasting a violet to blue color is not massive, but a beautifully transparent, facetable gem of exceptional color that rivals sapphire. The mineral is zoisite. You may think you are not familiar with it, but it is regularly touted on TV gem programs by its varietal name, tanzanite. Tanzanite is named after Tanzania, the country in which it was first found.

When experienced collectors hear the name zoisite, they think pink. That's because for decades the only important zoisite around was a massive pink variety called thulite. "Thule" is the ancient name for Norway, the country in which fine pink zoisite was found in the past. However, pink zoisite, a calcium, aluminum oxide hydrous silicate, has never been anything but a novelty stone. It gets its delicate color from the chromophore manganese.

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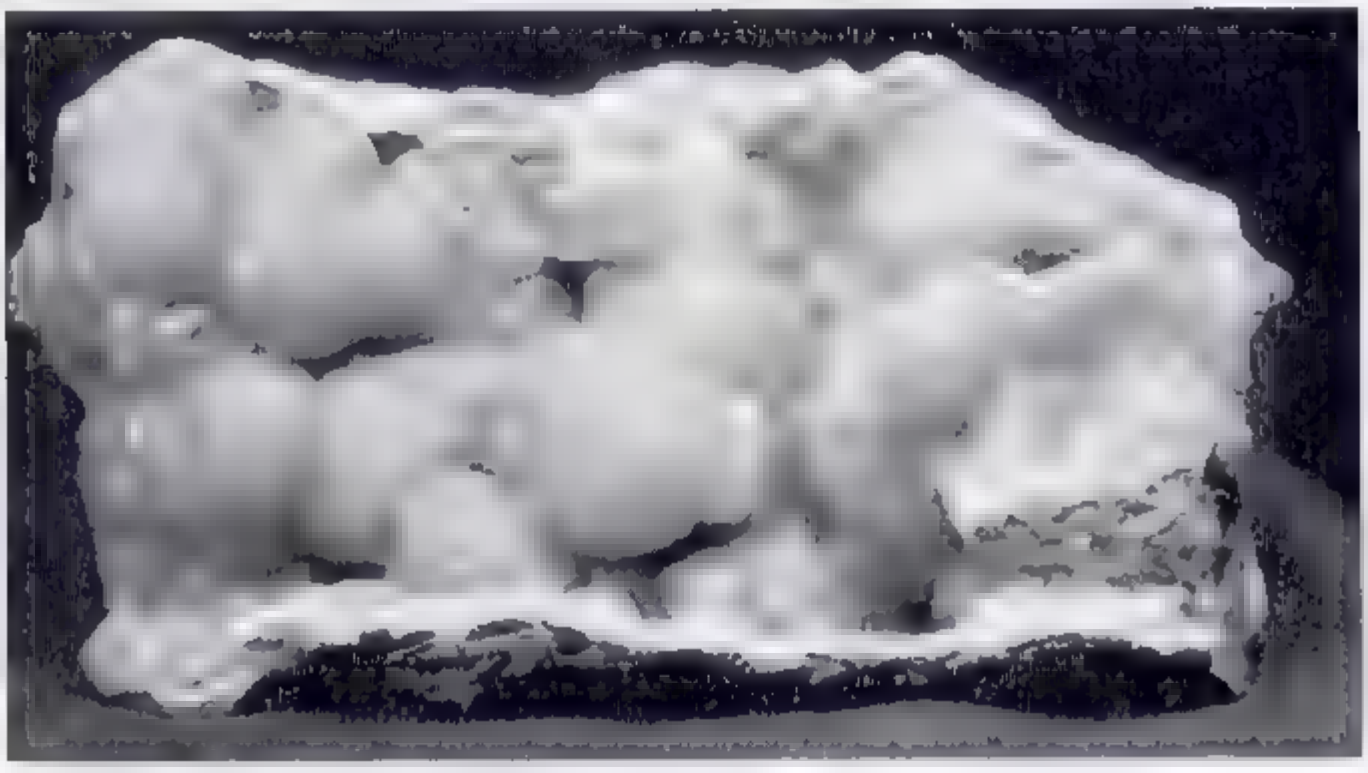

Infusing chrysocolla turns otherwise dull quartz into a lovely gem known as gem silica.

The attitude toward zoisite changed dramatically in 1967 when Manuel d'Zouza filed claims on a property in the Merelani Hills, some 40 miles from Arusha, Tanzania. The Merelani Hills are part of the Lelatema Mountains. Manuel thought he had found a sapphire deposit when he picked up lovely blue gem crystals. He immediately began to sell the gems to take advantage of his good fortune, and some finally ended up at the University of Heidelburg where, after proper testing, they were finally identified as zoisite, not sapphire. Of course, it was a most unusual form of zoisite, for instead of being the usual pink massive material, it was crystallized, blue and gemmy!

Gem experts in Europe and the United States immediately became involved with the gem. Specimens were shown to the gem experts at the Smithsonian and to several major jewelry companies. It was immediately recognized as a useful and very attractive gem. Once its origins were known, it was properly named tanzanite.

This naming came about at least in part because of my friend Campbell Bridges, who later discovered the superb green garnet tsavorite. Campbell was the fellow who showed a small crystal of this blue zoisite to the people at the Smithsonian. Coincidentally, he also showed pieces to the leadership at Tiffany's in New York. It was there that Henry Platt came up with the varietal name tanzanite.

Since its appearance in the late 1960s, tanzanite has taken the gem world by storm. It is a colorful, very interesting, and now valuable gem.

Remarkably, these orthorhombic crystals are found in a metamorphic deposit formed when hydrothermal solutions invaded the existing graphitic gneiss or dolomite. They come in a variety of colors, though most have only seen it in its most popular shade, blue-violet. Tanzanite can be blue, green, yellow, pink, brown, and what is sometimes referred to as khaki colored. So why do you see only blue tanzanite for sale? Do they simply throw away the other colors of stones? Of course not! They heat treat them to achieve the lovely, rich blue-violet color.

The people at Heidelberg had experimented with their stones and discovered that if tanzanite, whatever the color, is heated to about 700 degrees Centigrade, the gem crystal will turn a lovely and stable blue. Thus, the off-colored stones gained a useful new life. According to Bridges, this also means virtually all the tanzanite you see for sale today, including that offered on TV, has been heat treated. The very choice natural blue stones never see the commercial market, as they get special treatment in the gem trade. Some are even sold for their specimen value, especially if they are slightly internally flawed.

There's nothing wrong with heat treating crystals, as it simply rearranges the electrons that affect color. According to one reference, iron is the initial cause of some color in tanzanite, but manganese has long been credited with causing the blue color.

The only flaw I see in heat treating a stone is when the seller fails to tell the buyer of the treatment. On the positive side, heat treating makes far more gems available to the general public at affordable prices. It also explains why a premium is paid for natural stones. Can you identify a heat treated stone from one that is natural? I can't!

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The mines in the Merelani Hills—and there are several of them—have gone through some rough times. One year, there was a nasty flood when the banks of a nearby creek broke down and poured millions of gallons of nasty, muddy water into the mines and down the shafts. More than a dozen miners were unable to escape and drowned. It took weeks to clear the mess, shore up the creek, and get back to mining

Another interesting event at the tanzanite mines recalls the early days of mining in this country, when it was finders, keepers in mining. When a surface outcrop was found, anyone could move off a short distance and start mining sideways to cut into the vein belonging to someone else. It was not unusual for the original claimant and the interloper to literally run into each other during mining underground when one tunnel cut into another. Fights and even killings would be used to settle ownership of the vein!

This had to be stopped, so the Apex Law was enacted in this country. It protects the original prospector by allowing him to follow his surface discovery wherever it goes underground even if it crosses into another's claim

In Tanzania, there is no Apex Law During the mining of tanzanite gems along an underground vein, the workers in one mine tunneled right into a neighboring mine, breaking into the working face where a rival crew was hard at work A good old-fashioned fight ensued. I never found out whether anyone was killed, but you can bet plenty of miners had tool-induced headaches after the dust settled! It took time for that dispute to be settled so mining could be resumed Now reason prevails, and maybe it won't happen again.

Such events tend to interrupt production and affect the market price of gems However, there are several working mines in the area now, so unless a shooting war breaks out again, the supply of crystals for the gem/collector market will persist.

One of the fascinating features of tanzanite is a property called pleochroism, in which a crystal shows more than one color when viewed from different angles. Tanzanite crystals show trichroism, or three different colors Viewed through one face, a natural tanzanite crystal is blue. Turn the crystal 90 degrees to view through a second face, and the color is violet. Look down the long axis of the crystal, and you see a green, brown or reddish color. This is a function of the internal electron arrangement of tanzanite.

This property is seen in natural crystals before any heat treatment is applied, which suggests a way to detect treatment: Treated stones lose this feature.

The internal geometry of a tanzanite causes this phenomenon. When molecules arrange themselves, their electrons function in chemical reactions. In some cases, those same electrons can absorb light waves of certain wavelengths (colors) from the white light that enters the crystal. When they do this, the added energy causes them to shift position. The light energy they do not absorb is emitted from the crystal, and you see it as a color.

When the electrons that have absorbed light in pleochroic minerals shift to a new position, the distance they have to travel determines the energy they absorb. The viewer sees different colors from different directions because the electrons traveled different distances within the molecular structure and absorbed different wavelengths of light.

While zoisite, variety tanzanite, is costly because it is a very attractive gem, another form of zoisite has been around for over 50 years and is not at all expensive by comparison. You've seen a massive green-and-red material carved into ashtrays, bookends, spheres, small figures, and other objects. The green surface looks sugary and the red material (ruby) is in more or less opaque hexagonal shapes that often show a schiller effect when polished. The red ruby contrasts nicely with the green matrix dotted with black inclusions. The ruby is almost never gemmy, but the schiller effect, a bright line of light caused by the ruby's structure, makes it contrast nicely with the green zoisite. The black crystalline bits are an amphibole. By itself, the green zoisite would be interesting, but not particularly exciting! But with the lovely hexagonal plates of purple-red rubies, which can be anywhere from an inch to 6 inches across, this is very attractive lapidary material!

Apple-green zoisite/red ruby rock is found in the Matabuto Mountains near Longido, Tanzania, in Masai tribal territory. In fact, the locals call the material Anyoli, which in Masai means "green." This has led to the material often being called anyolite. The material finds its way into the American and European markets, but the more significant use is in the world-famous carving center, Idar-Oberstein, Germany.

The green zosite is referred to as chrome-rich, as its vibrant green color is due to that element. Chromium also creates the rich red color in ruby.

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The ruby crystals are not usually very gemmy, though the larger crystals may have small gemmy areas that can be retrieved by crushing the crystal. Thin-sliced zoisite/ruby material transmits green light coupled with glowing red hexagons, a lovely contrast!

One of the most common minerals found in any major porphyry copper deposit is chrysocolla. It's uncommon in the huge Michigan copper region, but where desert weathering can attack the original ores, this colorful secondary copper silicate abounds. It is safe to say chrysocolla will be found wherever copper minerals are exposed to weathering, even in minor amounts.

As a collector mineral, chrysocolla leaves much to be desired. It is exceedingly brittle, has a waxy blue color, fails to form in any discrete crystals of note, and is most often seen as a colorful smear on a rock! Yet, few copper minerals can equal the role that chrysocolla has played in the search for and discovery of copper deposits.

Prospectors are immediately attracted to any unusual form or color in rock outcrops, and the color of even a slight smear of chrysocolla acts as a beacon. This is how the great copper porphyry deposit at Ajo was found. Only a small amount of chrysocolla is needed to create a most appealing copper "bloom." More than once, this has been used by a promoter to scam investors into thinking what they are seeing is a rich source of copper.

Chrysocolla is often a minor, but important, ore of copper. For collectors and artists, however, it plays two prized roles. It can replace other minerals to form lovely blue pseudomorphs that collectors prize. It can also infuse its vibrant blue color into otherwise colorless chalcedony, creating what is usually referred to as gem silica. Some buyers visit copper mining camps to ferret out the blue gem, for which they will pay considerable sums!

If you have ever been to an open-pit copper mine, you are immediately struck by the blue coloring on dump rocks. These rocks, tossed aside by miners as being devoid of the red copper metal, still have value.

Chrysocolla rarely forms discrete crystals, and when it does, they tend to be hairlike, small and easily crushed Practically all the chrysocolla is found in massive form as earthy or porcelaneous masses in cracks and seams of rock. It is brittle and opallike in appearance. Its glossy luster is appealing, but the lapidary is hard pressed to make something out of this very friable mineral. Still, chrysocolla has found its niche in the world of décor.

Crystals of tanzanite are seldom seen, since most are gemmy and are faceted for gem use.

Ordinary rocks coated with chrysocolla become lovely decorative or construction stones. In the West, where copper mines abound, they have been used as colorful yard rock, in the construction of walls and fences, in rock gardens and fountains, and in rock fascia on homes and businesses.

It is thought that chrysocolla may start out as a colloidal gel, which may account for its lack of discrete crystals. This gellike condition allows it to ooze into cracks. When the rock is later blasted apart, the chrysocolla, a very poor cementing agent, shows up on one or more sides of rock fragments.

While this copper, aluminum hydrous hydrate silicate is itself a secondary mineral, it continues the breakdown process, altering to one of two uncommon species, plancheite and shattuckite. The latter was found in Bisbee's Shattuck Mine, while plancheite was first identified in specimens from Africa. These two minerals were undoubtedly seen long ago, but their identities were not established until the 1930s.

Collectors these days are certainly familiar with the soft, powder blue, massive material commonly seen on various copper-bearing specimens from Katanga. It often encloses superb red octahedrons of cuprite, which are very popular collector specimens.

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Much of this blue matrix material is plancheite, a mineral no longer considered rare.

Just when chrysocolla was recognized is not recorded, but it had to have been known long before Roman times, as it undoubtedly was an important aid in the discovery of ancient copper deposits in Cyprus and perhaps those in Eastern Europe. We do know it was recognized by the year 315 B.C. when Theophrastus wrote about it.

A really significant use for chrysocolla was in metalsmithing use when the Etruscans created their amazing gold objets d'art. They were very active miners and artists who enjoyed using gold. By about 500 B.C., they had developed a skill called "gold granulation," a technique now called "fusion weld bonding."

The process calls for tiny balls of metal, in this case gold, to be attached to a sheet of gold that has been shaped. These small beads create a design on the object or completely cover it, giving it a distinctive surface. The Etruscans' granulation process used gold almost exclusively. The process was eventually lost and remained unknown for hundreds of years. Luckily, excavations of Etruscan tombs unearthed gold granulation objects, though archeologists had no idea how Etruscan artists had achieved this beautiful use of gold.

The beauty of granulation is that it allows the artist to create three-dimensional designs and figures on a flat or curved surface, to which the beads can be added later. Modern metalsmiths were anxious to rediscover the granulation process. They finally achieved this goal in the early part of the 20th century.

Granulation, or fusion welding, of two metals is accomplished through the use of any of several different metal salts and minerals. It is believed the Etruscans used finely crushed chrysocolla. The original gold object was coated with a paste of the crushed copper silicate, then the small gold spherules were carefully placed on the paste-gold surface. The gold was then fired close to the melting point of the metal. The chrysocolla would smelt, releasing a thin layer of copper metal that would bond with the surface of the object and the tiny spherules. The name for chrysocolla may have come from the terms for this process: *chrysos* means "gold" or "golden," and *colla* means "glue" or "colloid."

Not all chrysocolla is crumbly; for the lapidary, it provides considerable inspiration. It can be an integral part of stones consisting of several colorful copper minerals. The well-known, colorful Eilat Stone from the Negev Desert in Israel, which some think is the location of the lost King Solomon mine, is colored in part by included chrysocolla in the agate.

Far more important, and certainly more exciting for the lapidary is gem silica, that wonderful and rare union of chrysocolla and chalcedony. Since it has the hardness of quartz, gem silica is a far more manageable gem than blue turquoise. Large amounts of this wonderful gem were found during the opening of copper pits in Arizona, particularly in the Miami-Globe area east of Phoenix. Large masses, some weighing tens of pounds, were found here before and during World War II, though little is found today. The limpid blue color of this chrysocolla in quartz is unmatched in any other gemstone.

The Pearl Handle Pit at Ray, Arizona, is a typical copper porphyry deposit with wonderful cuprite, native copper, and other crystallized species, including a lot of selenite gypsum crystals. In one instance, the chrysocolla gradually replaced the easily dissolved selenite prisms, producing wonderful, bright-blue, striated crystals that are pseudomorphs of chrysocolla-after-selenite gypsum.

Chalcedony can be infused with malachite and even azurite in rare cases, but much more common is chrysoprase, the green gem first found in Poland and more recently in two regions of Australia. In this case, the colorless chalcedony was infused with nickel salts, which give it a lovely, limpid green color. This delightful stone has been around for a couple of centuries.

Chrysoprase is much more common than gem silica, but not as valuable. Still, mining the gem makes an important contribution to the semiprecious gem market.

I was fortunate to visit a chrysoprase mine in Western Australia about 150 kilometers north of Kalgoorli, better known as a gold-mining region. The chrysoprase occurred in chalcedonic veins in an outcrop resembling a stockwork. The surrounding area was exceedingly level, typical of the outback.

The chrysoprase was mined using a bulldozer with a ripper hook on the back. The machine gouged the ground, revealing the seams and pockets of green rock. It was fun to walk along behind the bulldozer and simply fill 5-gallon buckets with bright-green gem material.

I'll conclude my series on silicates by discussing willemite, one of the more popular fluorescent silicates, which occurs in both massive and crystallized forms.

Rockhounding Bountiful Bancroft

Certain collecting areas at the Richardson Fission Mine require substantial digging and bedrock splitting to recover fluorite, calcite and apatite.

A Collectible Variety in a Small Area

Story and Photos by Mike Streeter

As Chrissy and I drove up and stopped in front of the closed gate of a Canadian border-crossing booth, a surprisingly young guard politely, but in a no-nonsense way, asked me, "Do you have any weapons or drugs in your possession?" Of course, I said "no" to his question, but I did wonder if our full arsenal of rockhounding tools in the back of our truck counted. I thought about saying, "No weapons, sir, but we do plan to dig a whole bunch of monster holes in your Canadian countryside with that arsenal back there!"

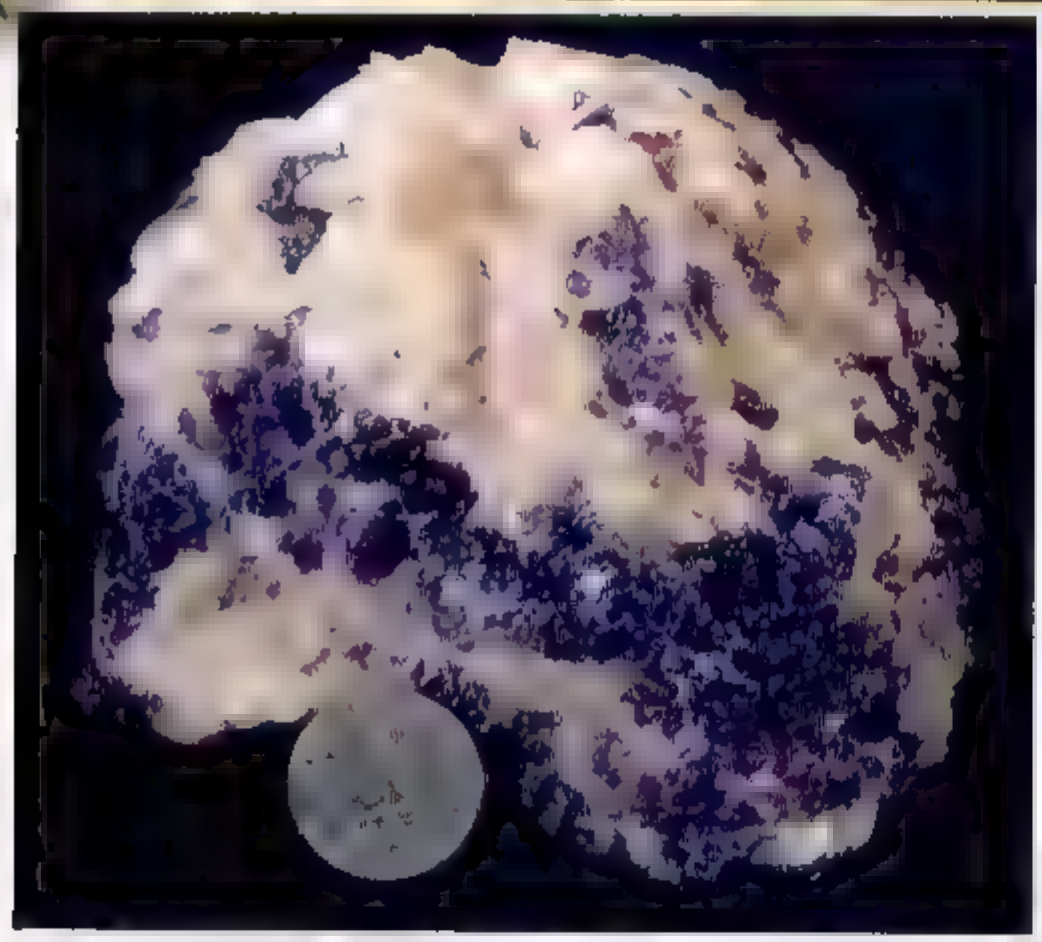
The guard then asked us where we were going and how long we would be in his country. I told him, "Bancroft" and "five days." Just as I thought that we might be in the clear, the guard's phone rang as if someone without a sense of humor had read my mind. The border guard wrote down a few numbers on an official-looking green sheet of paper, handed it to me and told me to pull over to the left so that our vehicle could be searched. I tried, but was unable to squelch the thought that whoever had read my mind must have been a strict environmentalist.

Apparently, the Canadian border guards are charged with searching a certain number of vehicles, because Chrissy and I certainly don't appear to be the Bonnie and Clyde type—at least, that is our perception. After about 10 minutes, one of the very polite young men handed me my keys and cheerfully told me to have a nice holiday

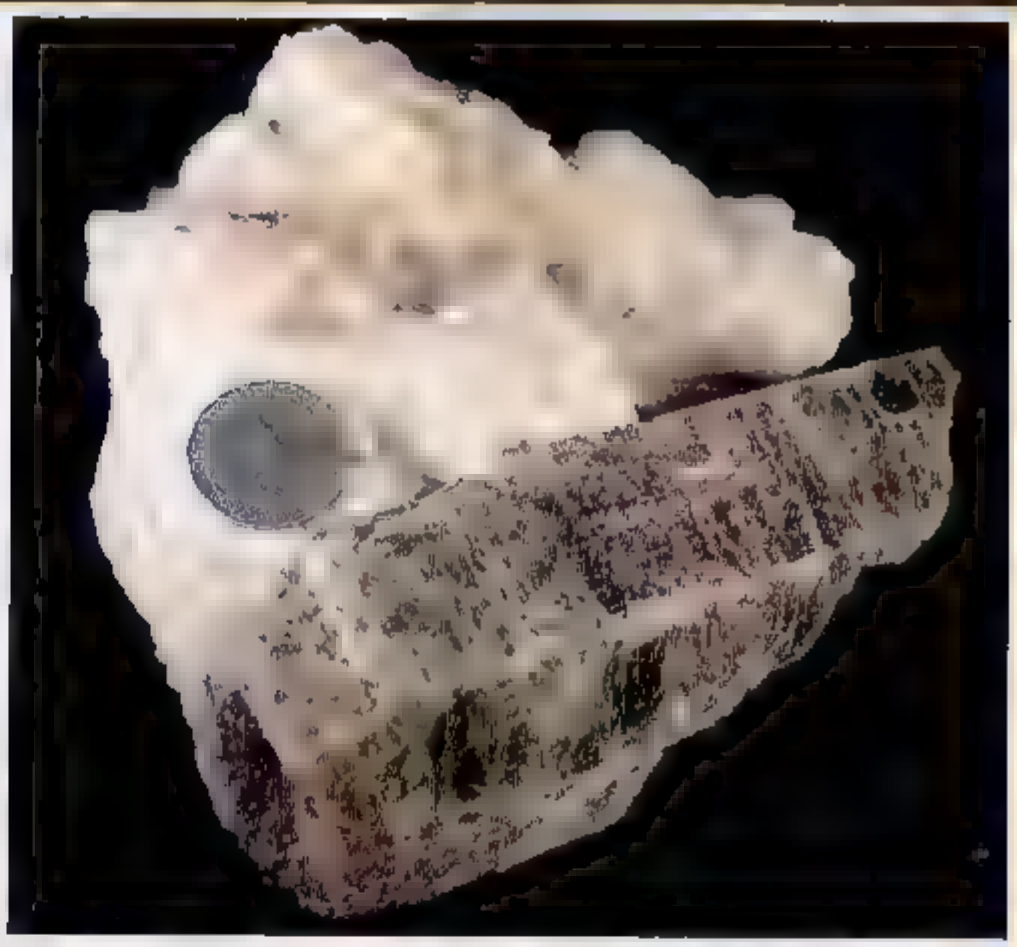
"Welcome to Canada," I said to Chrissy as we hurried off toward Bancroft

After talking for years about making a trek from our home in western North Carolina to collect in the world-famous Bancroft area, the excessive heat of another Southern summer made it an easy decision to head north into the heart of Ontario, Canada. Bancroft is world renowned among rockhounds for the incredible variety of rocks and minerals that can be collected in a relatively small area

The Bancroft-Corridor, or Bancroft Terrain, so named by geologists, is contained within the Grenville Province of the Canadian Shield in east-central Ontario. The Grenville Province formed approximately 1.3 billion years ago during the Grenville Orogeny, a plate tectonic event that affected the entire eastern North American continent. Subsequent geologic events, including plutonic intrusions, erosion, sedimentation, volcanism, metamorphism, and late stage fissure filling, formed the Bancroft-Modoc Corridor, which encompasses an area about 50 miles long by 15 miles wide. It is estimated that more than 4,000 mineral species have



The fluorite and calcite from the Richardson Fission Mine is wonderfully fluorescent when viewed under short-wave ultraviolet light.



It is reported that emerald-green and red fluorapatite crystals that can be measured in feet have been collected in the Bancroft area.

been identified within this entire region. During the mining boom of the late 19th and early 20th centuries, nearly 500 area mines and quarries existed to exploit the wide variety of minerals.

According to the Bancroft and District Chamber of Commerce, "a list of rocks and minerals that have been mined in the area include: corundum, feldspar, uranium, graphite, iron, nepheline syenite, mica, marble, granite, lead, gold, molybdenite, apatite, beryl, fluorite, talc and sodalite. In most cases, mining was carried out on a limited scale, between 1880 and 1935, and was largely confined to open cuts and quarries." City leaders proclaim Bancroft the "Mineral Capital of Canada" and boast of this fact on several strategically placed signs on major roads leading into town. It is hard to argue their claim, as more than 300 collectible minerals are known to occur in the Bancroft area. Rock and mineral specimens from this area are on display at numerous prestigious museums and in countless personal collections throughout the world.

We arrived in Bancroft in late afternoon on Monday, Aug. 15, 2005. Having heard from friends that the town is small and sleepy, we were somewhat surprised by its actual decent size and the hordes of cars and people bustling about. We were told that the summer population of Bancroft swells to nearly three times its winter population of 4,000 as tourists arrive from the cities to the south, especially from the Toronto area. The area's many lakes, rivers, old mines, and prospects supply endless recreational opportunities to boaters, fishermen and rockhounds.

We had made prior arrangements to stay at the Bancroft Tent and Trailer Camp (www.bancroftcamp.ca) in our folding camping trailer. Having discovered the campground online, I could only hope that the owner's representations about the facilities would turn out to be accurate. When we arrived at the campground, located a few miles south of Bancroft, we were pleased to find that our reserved spot had a wonderful view of Marble Lake. There was no cable television, but we did receive one Toronto station, so we would at least be able to stay abreast of the weather reports during our stay.

We awoke early on a beautiful Tuesday morning to the sound of honking geese on the lake. Our game plan for the day was to go to the Bear Lake diggings. We had stopped in at the Bancroft Chamber of Commerce the day before to obtain permits to dig there; $5 per person seemed like quite a bargain for such a famous and potentially rewarding location. Our trip was intended to encompass seven different collecting locations, and Bear Lake was a fitting first stop, as we had heard that just about all rockhounds new to the area head there first.

We drove out to the Bear Lake site, located about 40 miles west of Bancroft. The mosquitoes were waiting for us in force when we got out of the truck and started gearing up, but they pretty much left us alone after we swabbed ourselves with 100 percent DEET liquid. We had heard lots of horror stories of about how bad the area mosquitoes, blackflies, deerflies and horseflies were, but none ended up presenting much of a problem at all. I guess the dry summer, coupled with the already cool overnight temperatures, had lessened the volume of pesky bugs. A word of caution though: Try not to get any DEET on your lips unless you don't mind having them go numb and drooling on your chin.

We made our way to the digging area just off the dirt road and parking area. There was no question where prior digging had taken place, as there were huge holes and piles of dirt over a wide area beneath the thick forest canopy. A series of parallel "fissures" run in a generally north-south direction. These fissures are actually the remains of large calcite veins after much of the calcite has been weathered away from infiltrating acidic groundwater. The fissures at Bear Lake are known to contain very large fluorapatite crystals, hornblende, feldspar, biotite, and titanite. Some of the minerals are loose in the soil due to weathering, while others may be found still embedded in calcite.

We searched the area for a likely place to dig and ended up concentrating on a fissure nearest the top of the hill. Not knowing exactly what to do, I started digging in an area where it appeared that someone else had dug. Whenever in doubt at a new place, I will usually dig in a spot that appears to have been freshly dug and where someone has done some obvious high grading. This method doesn't always work, but at least it allows me to get a feel for what's underground. Chrissy sniffed out her own location and began scratching around, looking for some goodies.

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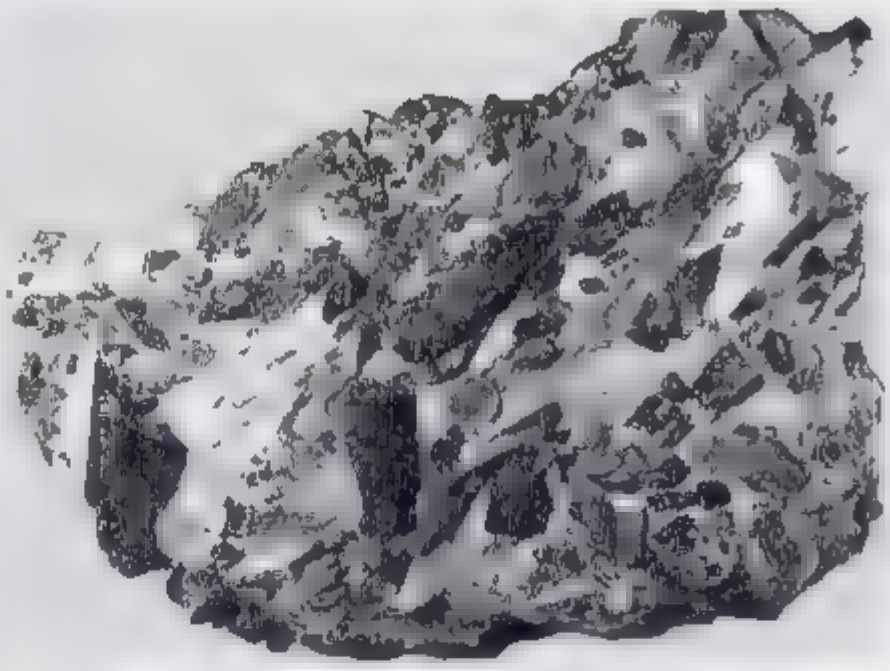
I could see that many of the fissures extend tens of feet belowground like narrow, dark caves that require lights and a lack of claustrophobia by those who would be brave or foolhardy enough to crawl down inside. I've never been much for venturing into deep holes or narrow caves, so I left these open fissures alone and concentrated on creating a few of my own from the ground surface down. I started digging in an area in line with a small fissure. Before long, I had punched my way into a pocket that was partially filled with excellent feldspar crystal clusters. Some of the clusters contained small fluorapatite and large, weathered hornblende crystals.



Fluororichterite, a member of the amphibole group, has only been identified in one world location: near Wilberforce, Ontario

While I was digging out my pocket, Chrissy came over to announce that she had uncovered some very large calcite boulders full of apatite crystals. She had already recovered quite a pile of loose apatite crystals from the soil surrounding the boulders. Her problem was that that the boulders were much too large for her to move, so she asked if I would help her. Since I had already pretty much reached the bottom of my small pocket, I went over to do battle with the boulders. I was able to move some of the boulders with my large mattock and pry bar, at least to the point where I could whack them up with hammer and chisel.

I soon found out that recovering whole apatite crystals in matrix is very difficult, as they are generally fractured and the calcite pretty much breaks where it wants, usually across apatite crystals. Still, we were able to extract quite a few keepers before the day was over. After beating on the boulders for a couple hours, we finally called it a day and headed back to camp for food and to rest up for the next day. Our rock hound, Opal, was especially pleased, having spent the entire day chasing (but not catching) chipmunks.

Wednesday morning, we drove out to the Silver Crater Mine to hunt for apatite, biotite, hornblende, and betafite. We stopped by the owner's house and left the $1-per-person fee in a jar on the porch. How's that for a bargain price? The 1½-mile two-track road from the house to the mine is quite rugged in places and generally requires a high-clearance four-wheel-drive vehicle. Our Dodge pickup made it with no problem, but the drive would have been problematic later in the week when it was loaded down with more rocks. We were accompanied on our drive by a swarm of deerflies. We were expecting to be eaten alive when we got outside at the mine, but the deerflies didn't seem particularly interested in human flesh and pretty much cleared out and left us alone.

We scratched around the spoil piles below an open cut for a while and found some very nice, dark, and very large biotite crystals, some in a calcite matrix. Some of the spoil pile specimens contained somewhat weathered apatite crystals scattered amidst the calcite and biotite matrix. The dark color of the biotite makes for a striking contrast with the white and pink calcite. There were incredibly large hornblende and biotite crystals in the side of the open cut, but it would have taken explosives to recover them. I asked Chrissy if she had brought any dynamite, but she told me that she had left it at home in her Sherman tank.

I was pretty much done and ready to pull out at midafternoon, but Chrissy asked me to come over to where she had been scratching to look at something "interesting" that she had found. There was a time when I used to roll my eyes at one of these requests, but either Chrissy is getting much better at finding stuff or maybe I'm getting more patient (don't laugh), so I walked over to see what she had found. Sure enough, Chrissy *has* gotten much better at finding stuff! She discovered an area where someone had high-graded what appeared to be perfectly good apatite crystals in calcite. Before long, I had discovered where the material had been retrieved from the bedrock. I began breaking rock and finding excellent apatite-in-calcite specimens. Not only was the apatite plentiful, but it appeared to be much gemmier than the Bear Lake material. I worked for several hours and recovered some excellent specimens, including a couple betafites in matrix.

On Thursday, we decided to take a crack at the Richardson Fission Mine. This location is perhaps best known for a rock containing highly fluorescent pink calcite and dark purple fluorite. Some of this material even contains green apatite, making for very striking specimens. Collecting at this location requires about a ¾-mile hike in. We parked at the head of a two-track road, grabbed our gear and tools, and started hiking. About a third of the way there, I remembered that I had forgotten to bring two 5-gallon buckets for carrying specimens back to the truck. I dropped my pack and tools and ran back to fetch the buckets while Chrissy and Opal waited patiently for me.

We came to well-worn side-trail leading upward from the road to the main collecting area. We spent much of the day collecting in the extensive spoil piles above an adit. We recovered our best fluorite/calcite and apatite specimens from a boulder in the hardrock digging area. Some of the rock was neatly banded with layers of calcite and fluorite and contained green apatite. I recovered a very large and somewhat misshapen, but shiny, apatite crystal that contains dark-purple fluorite inclusions from the spoil piles. Between the two of us, we were quite successful at the Richardson Fission. We almost did too well. Carrying the two three-quarters-full buckets back to the truck proved quite a challenge, but I finally managed.

When we drove away from the Richardson Fission Mine, we were tired and my arms were about 3 inches longer, but we still had a couple of hours left to fill out the afternoon, so we decided to make quick passes at several relatively close sites on our list.

Our first afternoon stop was at the Grace Lake road cut, where it is reported that fine diopside and tremolite can be recovered. The site, on a slope above the road, is rather small, but extensively dug. We saw lots of holes and plenty of rocks, but not too much diopside or tremolite worth taking home. Due to its small size and close proximity to the road, I imagine the spoil piles and leaverites stay pretty well picked over. I concluded that this site would require some substantial digging, and I wasn't up to the challenge that day. However, we did manage to find one decent tremolite specimen for the trouble of stopping by.

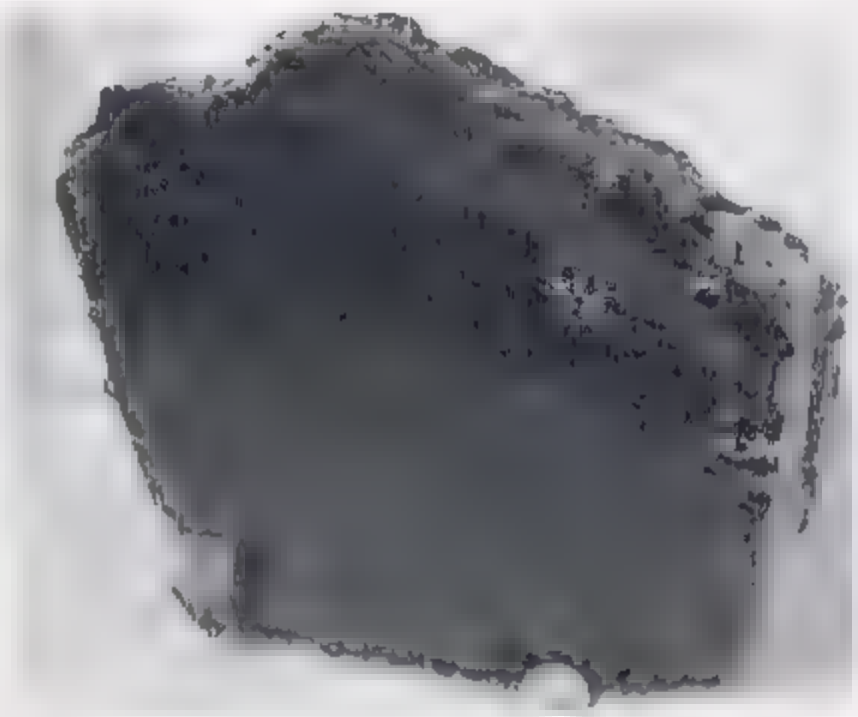
Our next stop that afternoon was the fluororichterite road cut. This road cut consists of a small section of hard rock composed of mostly fluororichterite and biotite in pink and white calcite. The gently sloping face has been extensively worked with hammer and chisel to remove chunks of rock. There were even numerous saw marks in the bedrock and a large boulder at the foot of the cut that had been sawed off. I quickly whacked off a nice chunk of rock from this boulder.

It must have been my lucky day, as I found a large section of rock containing numerous and large fluororichterite crystals. It appeared to me that someone had spent a great deal of time and effort trying to remove this section of rock, but had to give up on account of darkness, because they were almost there! It took me all of about 25 minutes to remove a whopping 75-pound specimen. Satisfied with this result, we decided to move on.

continued on next page

Rockhounding Bountiful Bancroft *from page 31*

Our last Thursday stop was at the Wilberforce road cut. This location is known for unusually large diopside crystals. This tiny road cut didn't show too much potential at first glance, but when we checked the riprap from the cut that had been deposited next to the highway, we were able to recover a few very large diopside crystals in clusters. The crystals are somewhat weathered and homely, but euhedral and up to about 6 inches long. We accepted these specimens as good enough for 20 minutes of work.



Very large and shiny black books of biotite abound at various Bancroft-area mines.

It rained for the first time Thursday night, but let up by Friday morning. The break in the rain allowed us to visit the last place on our list, the Quirk Lake Occurrence, where hornblende, feldspar and apatite have been found. We were told by our friends Ron and Faye Burke that they had found quartz crystals at this location on a July 2005 trip, but they must have dragged home every one, because we didn't see any. This small location is a series of fissures that run at about a 60-degree angle to the road. Some of the fissures are quite deep and very narrow. It would take a very skinny and brave man to crawl down into one of these openings. I am definitely not skinny and am an unabashed coward when it comes to crawling into confined underground spaces, so I spent my time digging rock and dirt out of the end of one of the fissures that appeared to have been purposely buried. Chrissy scratched around one of the shallower dirt-filled fissures to see what she could uncover.

After several hours, I managed to dig a rectangular hole that was about 6 feet deep and big enough to bury a large horse. Before long, the rain returned, but this was just as well, because I was too tired to make a serious attempt at breaking the bedrock at the bottom of my hole. We did find several feldspar and hornblende crystal plates and a single apatite crystal in calcite that are at least good enough to say that we have been there and done that.

By early afternoon, the rain let up again, and we were able to play tourists in downtown Bancroft. We experienced the culinary delight of lunch at one of the area's many "Chip Wagons." We had passed literally dozens of these during the week and weren't quite sure what they were and why there were so many of them. We found out that Chip Wagons are the Canadian version of small burger joints, except that they are most often contained in permanently parked bread truck-type vehicles with side serving windows. Based on the sheer number of these establishments, they must be lucrative businesses to own and operate. We feasted on burgers and a sackful of the best short-cut fries that we had ever had. While we were eating, Opal had her ears expertly massaged by a nice teenage girl who was waiting for her order to come up.

That evening, we met and shared supper with our friends Arnim and Betty Walter, who had driven up from London, Ontario, to spend a few days collecting. Arnim's severe arthritis has put his best collecting days behind him, but he and Betty still managed to get around and pick up a rock or two during their time in the area.

We were up early Saturday morning. The rain that had fallen most of the night conveniently stopped just long enough to allow us to get our things together and bring down the camper. We were anxious to hit the road and to get back to our beloved United States. Overall, we found our Canadian hosts to be very gracious, but there is no place like home.

For more information about rockhounding in the Bancroft area, visit the Bancroft Area Chamber of Commerce's Web site, www.bancroftdistrict.com/Tourism/Mineral_collect.php. The Chamber of Commerce sells a collecting guide that we found essential to our trip. Check out www.mcrocks.com/page18.html for two Bancroft-area field trip reports that include numerous site and specimen pictures. You may also find it useful to go the McRocks.com message board at www.websitetoolbox.com/tool/mb/mcrocks to ask specific collecting advice while planning your own trip.

Part II: Rio Arriba, Sandoval, San Juan, San Miguel, Sierra, Socorro, Taos, and Valencia Counties

Story and Maps
by David and Clois Walker

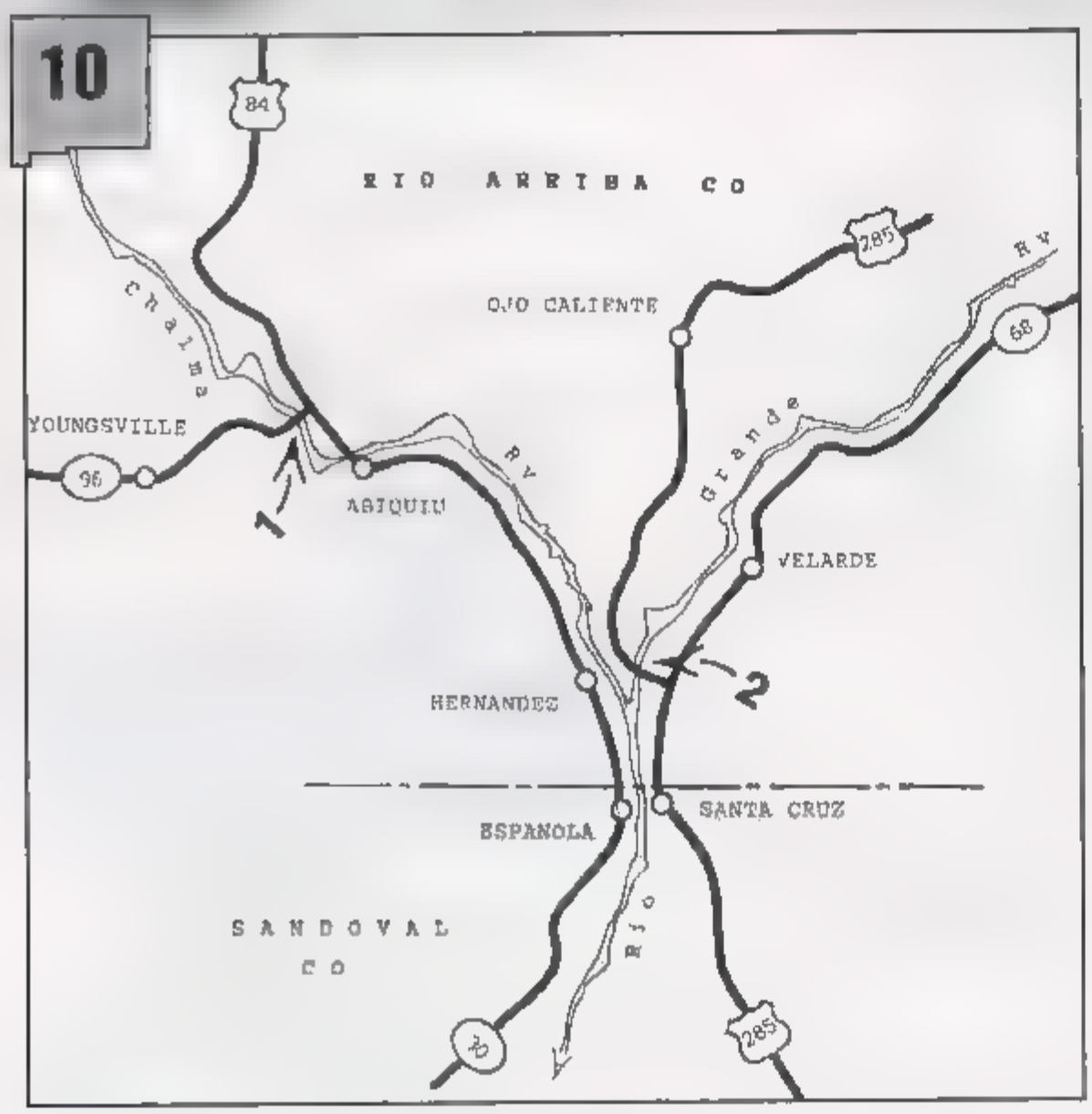
This is the second in a series of two articles containing maps that indicate suggested panning and screening sites at New Mexico highway/stream crossings where appreciable finds have been previously reported in vicinity watersheds. The principles of erosion make it likely that minerals and gemstones have been deposited in river gravels, awaiting removal by a rockhound with a pan. This is a speculative study; whether conditions at these sites are conducive to panning activities and whether minerals can indeed be found have not been investigated.

By confining operations within government-purchased highway rights of way, panners are spared the necessity of locating and obtaining permission from adjoining property owners, including state and national parks and Indian reservations. However, readers run the risk of prosecution if they cross onto private land, whether purposely or inadvertently. In instances where rights of way have merely been leased, other rules may apply.

Right of way access varies from state to state and within states according to the various authorities that oversee federal, state and county roads. Making a few phone calls ahead of time to verify access rights can save you headaches down the road.

Remember that the government to which these rights of way belong has some regulations of its own. Observe highway safety and environmental standards, such as parking only where designated, and using only a pan and scoop.

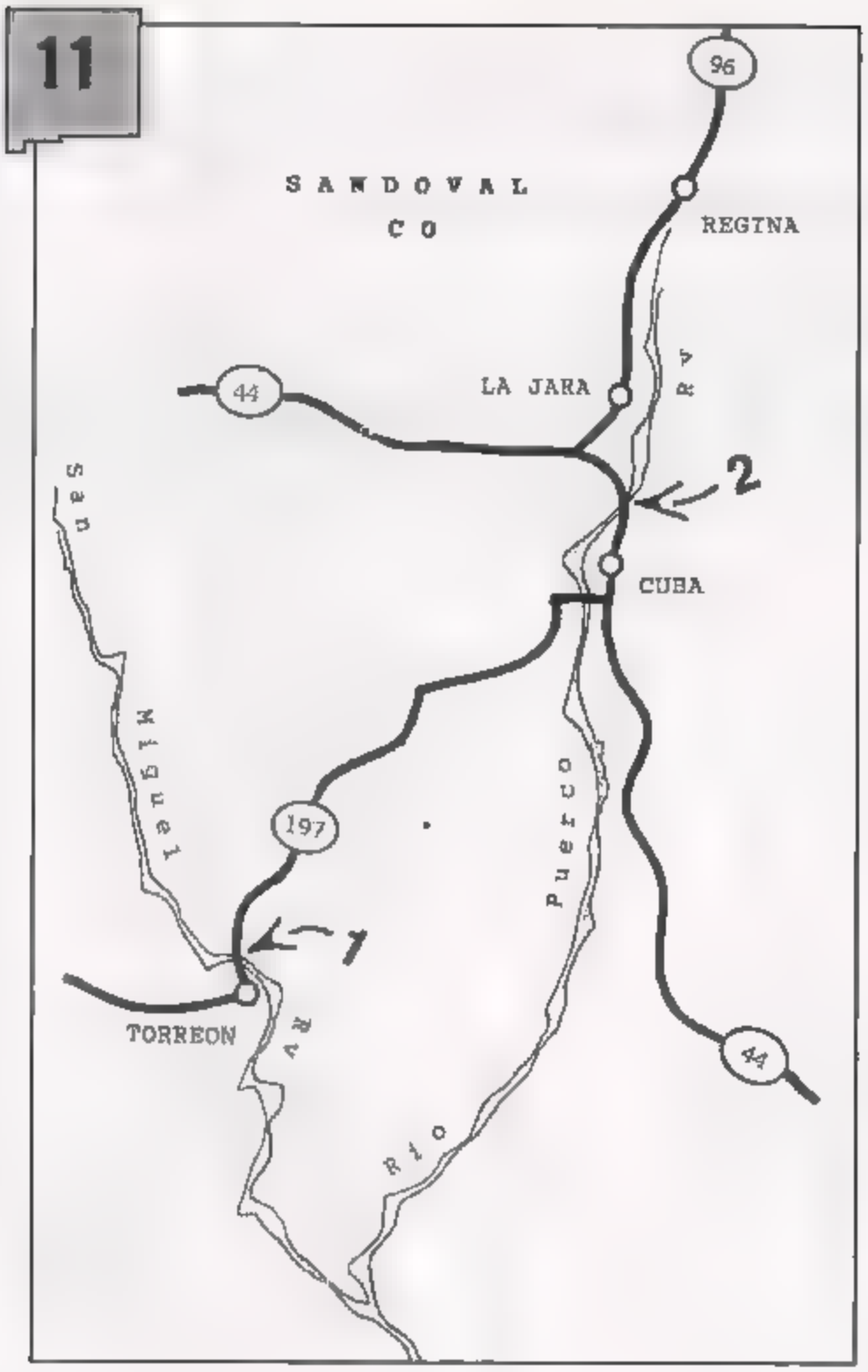
The maps provided contain the most up-to-date information available to us, but it is advisable to consult a current state highway or county map when planning an outing, for overall orientation in the field and because highway designations have been known to change.



RIO ARRRIBA COUNTY [MAP NM10]

Site 1. **Rio Chalma River/state Route 96** crossing near **Abiquiu.** Vicinity finds include malachite and onyx.

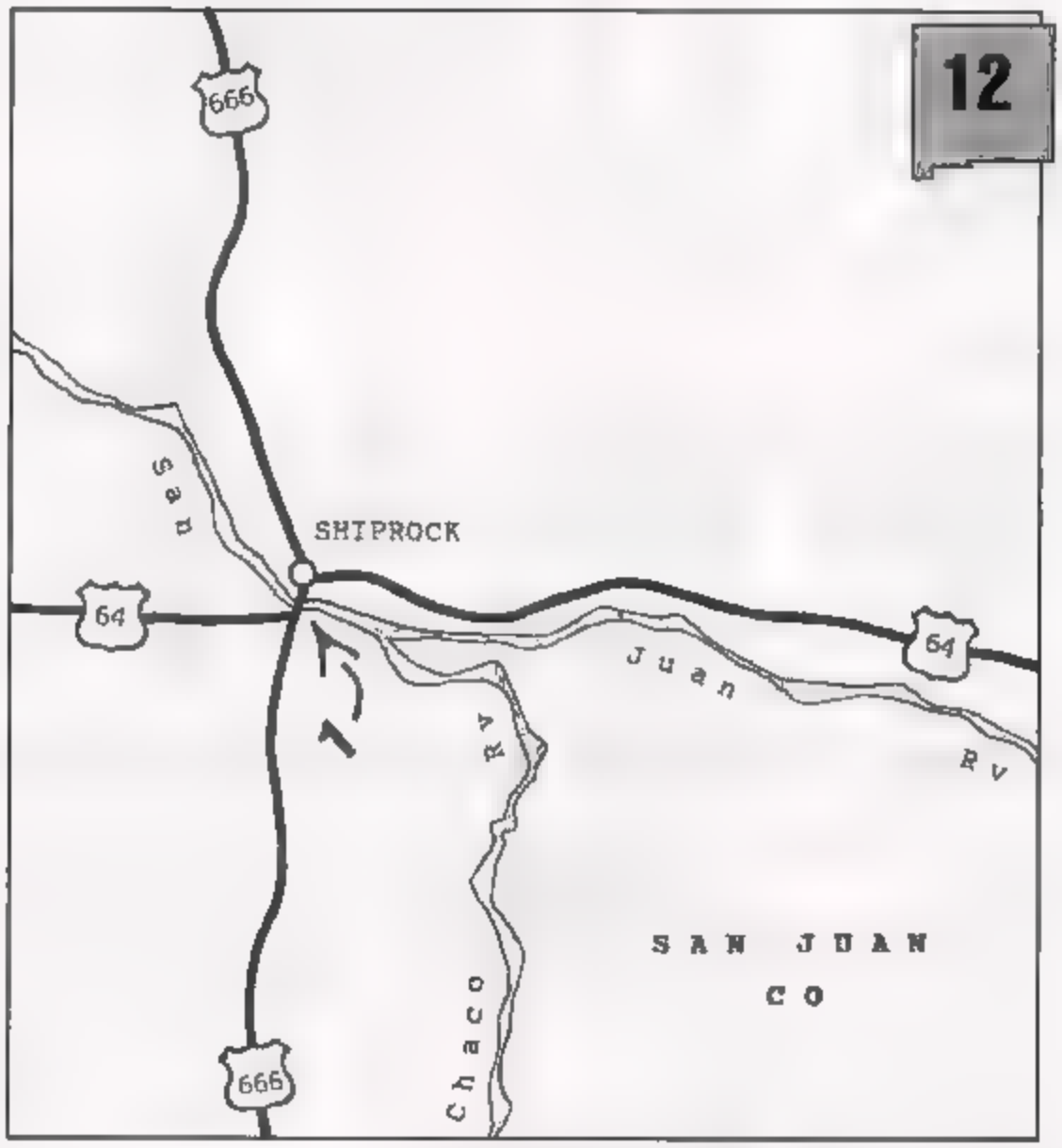
Site 2. **Rio Grande River/U.S. Highway 285** crossing near **Santa Cruz.** Vicinity finds include garnet, labradorite and malachite.



SANDOVAL COUNTY (MAP NM11)

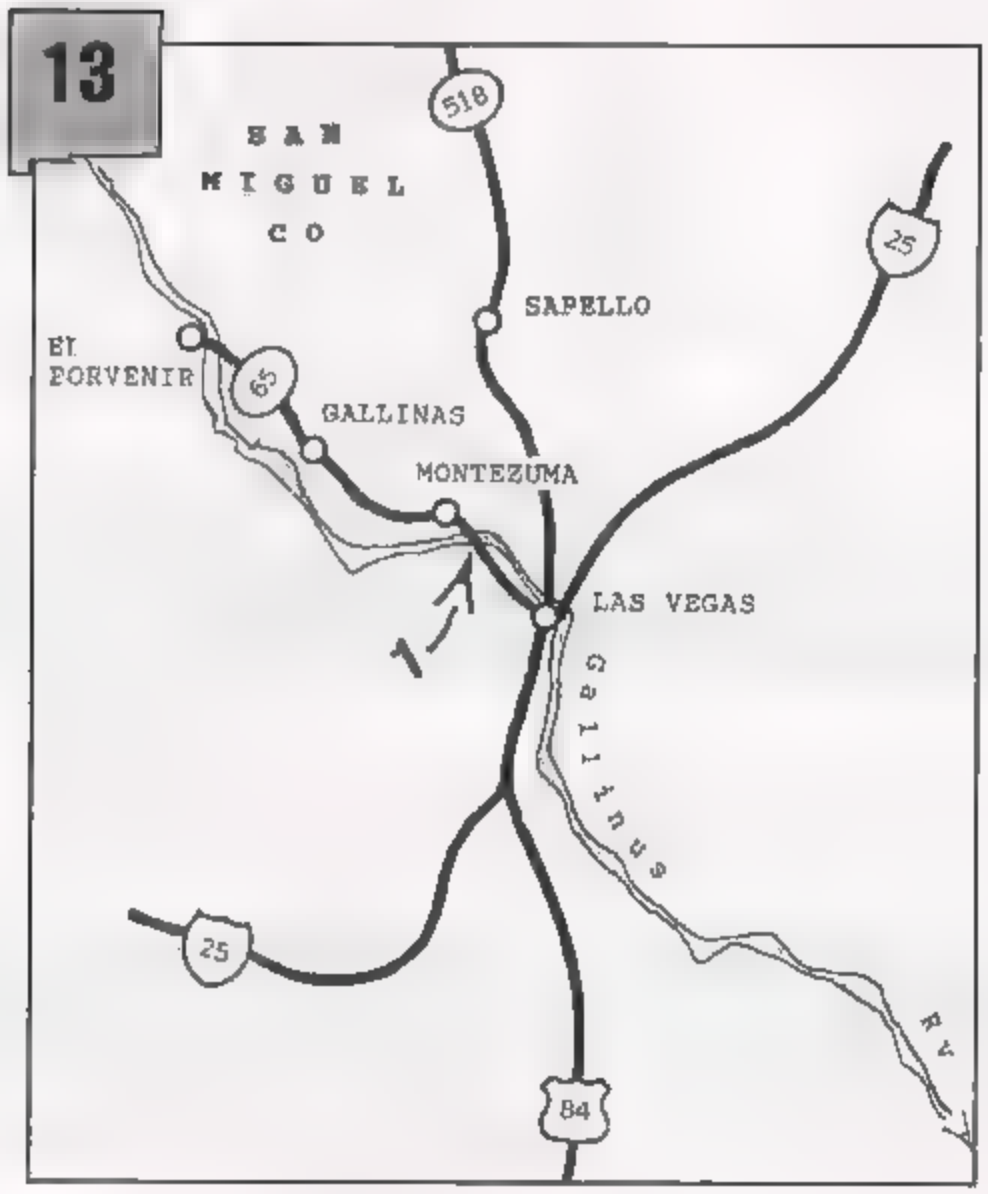
Site 1. **San Miguel River/state Route 197** crossing near **Torreon.** Vicinity finds include agate, chalcedony, chrysocolla, malachite, opalized wood, and quartz crystals.

Site 2. **Rio Puerco River/state Route 44** crossing near **Cuba.** Vicinity finds include agate, chalcedony, chrysocolla, and malachite.



SAN JUAN COUNTY (MAP NM12)

Site 1. **San Juan River/U.S. Highway 64** crossing near **Shiprock.** Vicinity finds include garnet, jasper and silicified wood.



SAN MIGUEL COUNTY (MAP NM13)

Site 1. **Gallinus River/state Route 65** crossing near **Montezuma.** Vicinity finds indicate silicified wood.

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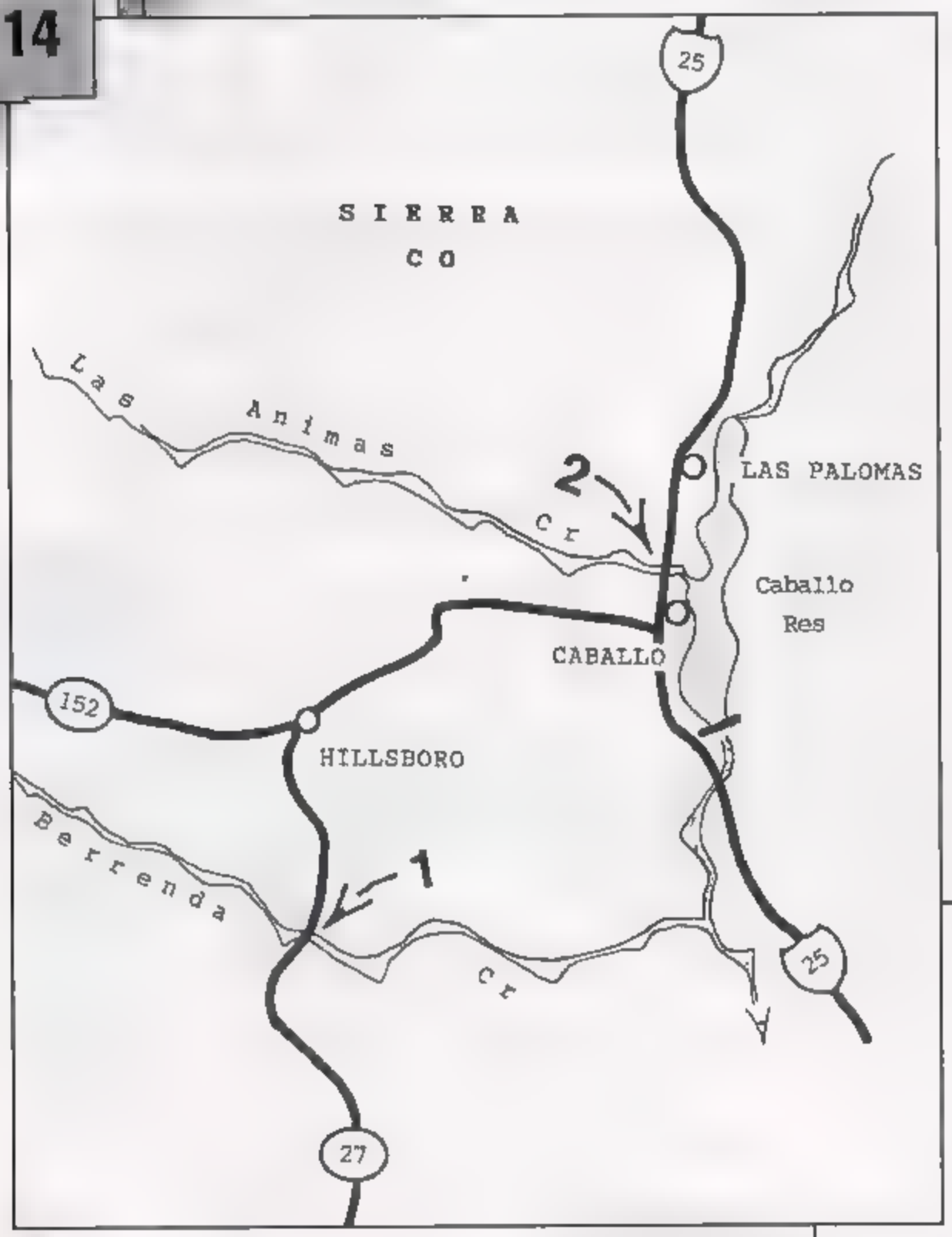
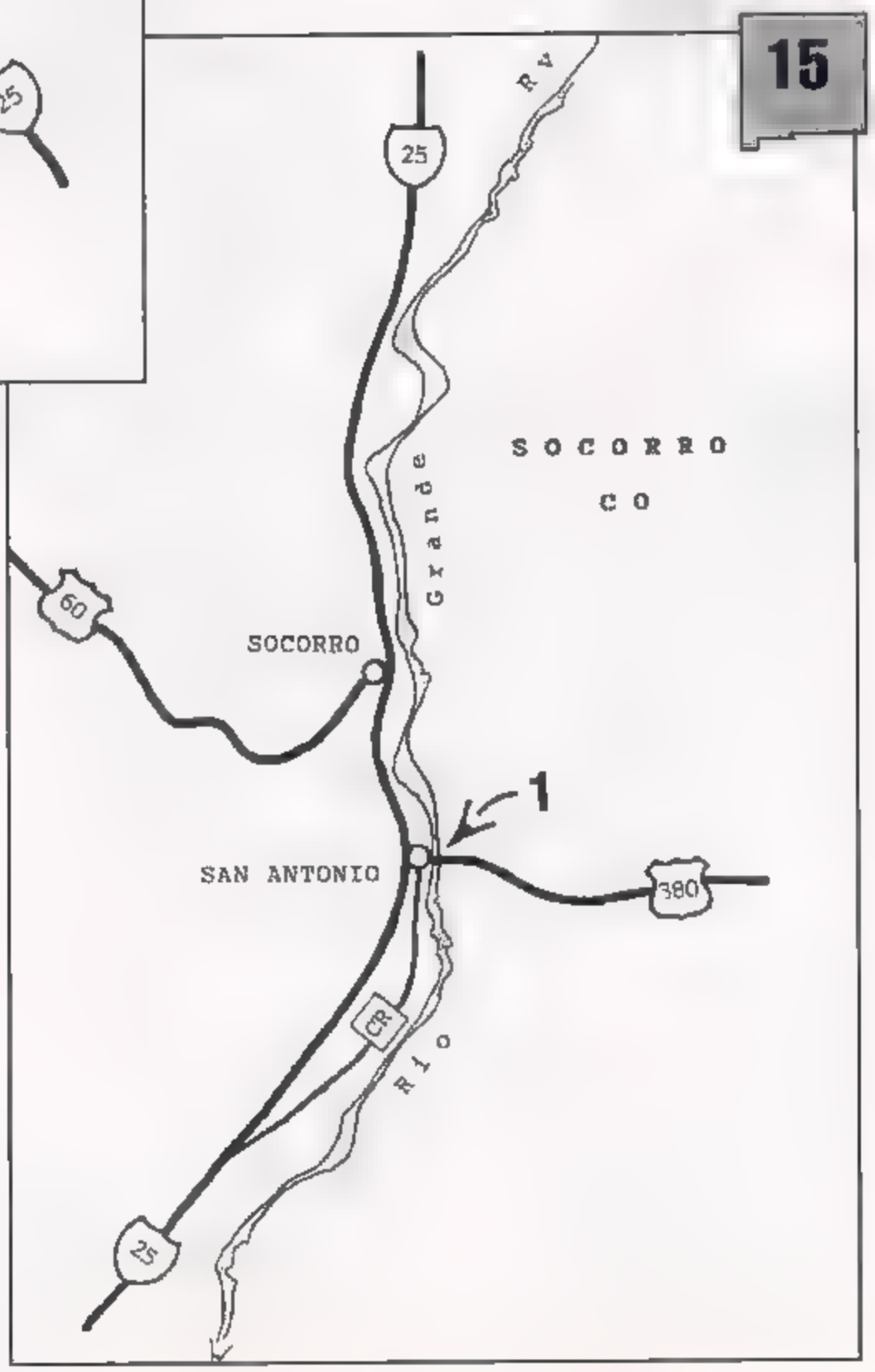


SIERRA COUNTY (MAP NM14)

Site 1. **Berrenda Creek/state Route 27** crossing near **Hillsboro.** Vicinity finds include agate, chalcedony, chrysocolla, gold, jasper, and quartz crystals.

Site 2. **Las Animas Creek/Interstate 25** crossing near **Caballo.** Vicinity finds include amethyst, gold, jasper, malachite and sphene.



SOCORRO COUNTY (MAP NM15)

Site 1. **Rio Grande River/U.S. Highway 380** crossing near **San Antonio.** Vicinity finds include agate, chalcedony, jasper, and quartz crystals.

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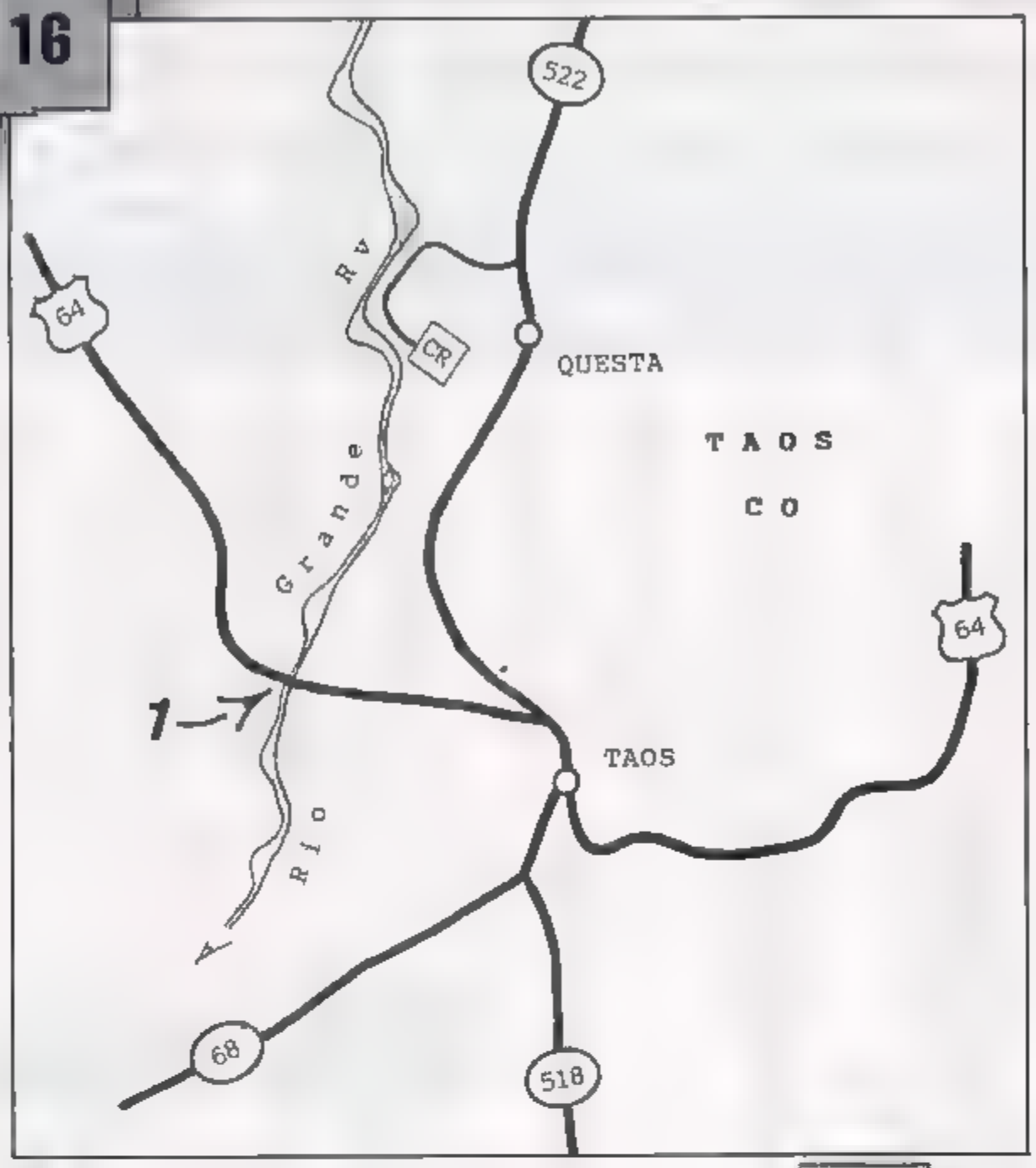
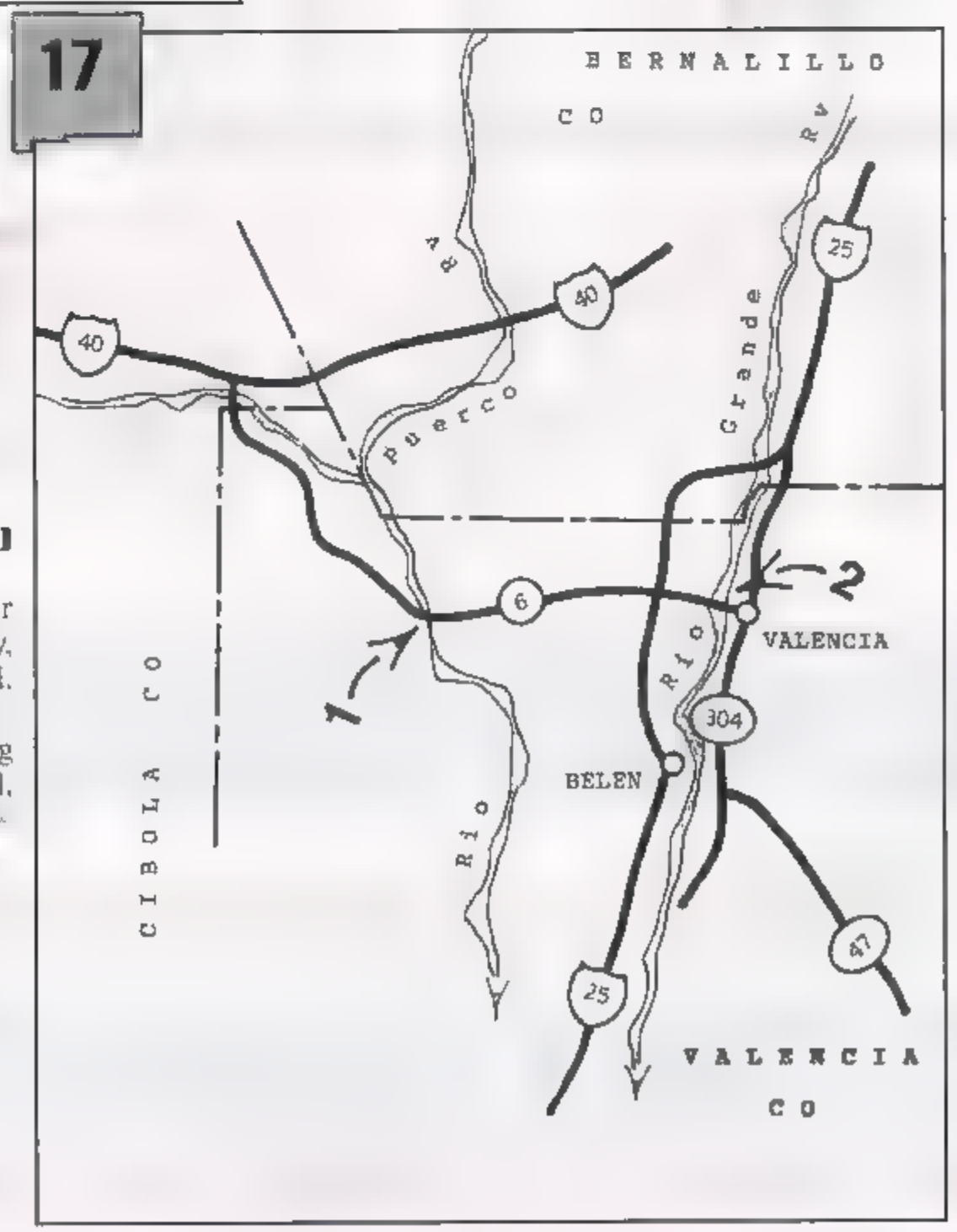


TAOS COUNTY (MAP NM16)

Site 1. **Rio Grande River/U.S. Highway 64** crossing near **Taos.** Vicinity finds indicate gold potential.



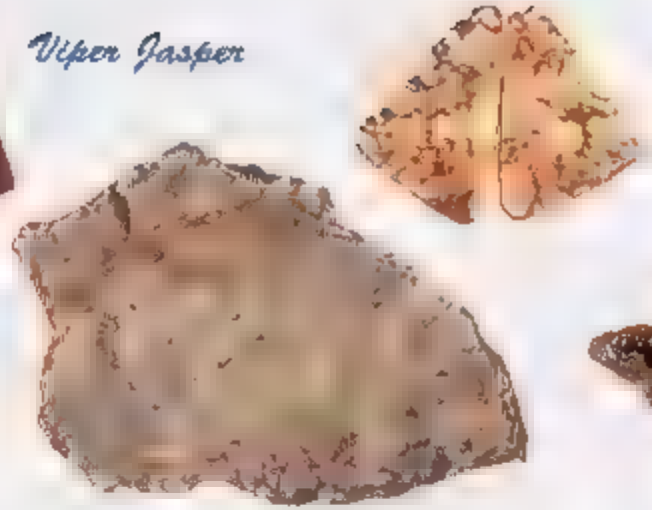
VALENCIA COUNTY (MAP NM17)

Site 1. **Rio Puerco River/state Route 6** crossing near **Valencia.** Vicinity finds include agate, chalcedony, jasper, opalized wood, and silicified wood.

Site 2. **Rio Grande River/state Route 6** crossing near **Valencia.** Vicinity finds include agate, opal, opalized wood, and silicified wood.

Cabernet Jasper

Viper Jasper

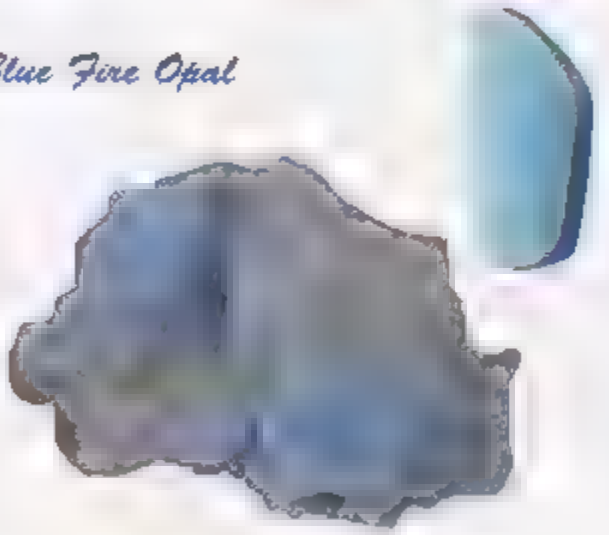


Mexican Chinese Writing

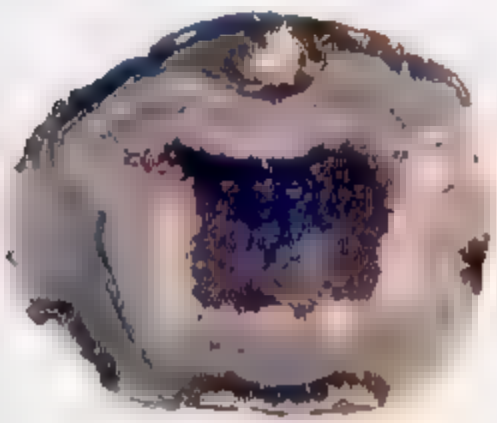
Hickoryite

Black Garnet

Blue Fire Opal



Las Choyas Geode



Trancas Geode

Talc

A Different Kind of Rock

Story and Photos by Chloe R. Young

The powder women put on their faces, the powder we shake on after a shower, and the foot powder we pour in our shoes is a natural mineral. All my life, I thought powder was a synthetic material, but it's not.

This same mineral is in all Wrigley's chewing gums. Every paint manufacturer in the United States uses it in their paint, and automakers put it in the ceramic part of catalytic converters. It's a natural mineral called talc.

Talc is made up of magnesium, silicon, oxygen and water. It is a soft mineral, representing number 1 on the Mohs Scale of Hardness. To be designated a mineral, a substance has to be a solid, inorganic, and naturally occurring in nature. The chemical composition must be definite, but not fixed, and homogeneous (not able to be broken down in structure), and the atomic structure definite, but not always fixed. Talc, $Mg_3Si_4O_{10}(OH)_2$, meets all these requirements.

Talc begins as a liquid. Hot water carrying magnesium and silica in solution react with and replace beds of dolomitic marble. The marble is metamorphic rock formed from dolomite that changed form under heat and pressure below the Earth's crust. The majority of U.S. talc deposits are those that replaced metamorphosed dolomite. They are usually white and are the purest form of talc. This type of deposit accounts for almost 50 percent of the world's talc production. The talc in southwest Montana formed in this manner more than 1 billion years ago. The deposits range from centimeters thick to the 29-meter-thick talc body at the Treasure Chest Mine near Dillon, Montana.

Talc can also form from the alteration of igneous rocks. Fluids react with magnesium, iron and other dark-colored (mafic) minerals in host rocks, ultimately replacing the mafic minerals with talc. These talc deposits are tabular (thin sheets) or lenticular (flat, oval-shaped) bodies reaching 325 feet thick and more than 975 feet long. This type of deposit is mined in Vermont and the eastern United States. The material is known as "soapstone" because of the dark coloration resulting from impurities in the rocks.

The colors of talc vary from a light white-green to apple green, dark green, brown, or pink. The color depends on the amount of other minerals in the rock, such as aluminum, iron, manganese and titanium. Talc is composed of weak bonds among microscopic platelets. This weak bonding enables the platelets to easily slide past one another and causes the soft, greasy feel of talc.

Polished talc is smooth and shiny, with a marblelike appearance.

The dried talc is ground into a fine powder and poured into 50- and 3,000-pound bags.

Found all over the world, talc is mined only by countries that think they can benefit from the mineral. China is the world's largest producer of talc, with a quarter of the world's supply. Its main products are talc lump, talc grain, and calcspar. The size of the talc powder is between 325 mesh and 3,000 mesh. The major uses of their talc are in paint, electric cable, ceramics, cosmetics, pharmaceuticals, and paper.

The United States is the second largest producer, with mines yielding around 1 million metric tons of crude talc ore per year in an approximately $100 million-dollar-per-year industry. Germany, Italy and Austria are also high in talc production, while South Africa, Scotland and Brazil have large talc deposits.

The Yellowstone Mine, near Ennis in southwestern Montana, is the United States' largest producer of talc. Luzenac America, which owns the mine, is part

The lighter apple-green color of this piece of talc is caused by a small amount of mineral impurities.

Deposits of replaced dolomite are usually white and are the purest form of talc.

The alteration of igneous rocks reacts with dark-colored minerals, creating the deposits known as "soapstone."

of the Luzenac Group of companies from France, the world's leading talc producer. The Luzenac Group produces, ships and sells in excess of 1.4 million tons of talc from more than 30 talc mines and processing plants in Europe, North America, Central America, and Australia. When one of the group's mines closes, the company restores and re-vegetates the land with appropriate plant life. Decommissioned buildings are dismantled, refurbished, or handed over to the local community. Luzenac's largest mine, Trimouns, in the French Pyrenees, attracts more than 10,000 visitors each year.

Barretts Minerals ships 130,000 tons of talc every year from its mill south of Dillon, Montana. It has two sites in this area, the Regal Mine and the Treasure Mine. Barretts is a subsidiary of Specialty Minerals Inc., with mills in New York, Texas and California. This Montana talc is so pure it cannot be used in cosmetics because the molecular structure will not take a fragrance. Luzenac and Barretts are the only companies in the United States that mine their own talc. The other mills have the talc shipped to them for processing

Other U.S. deposits occur in Vermont, Alabama, Montana, California, Nevada, Washington, Idaho, New Mexico, and Texas.

The process of formation determines the qualities of the talc. The grain size, shape, color, and purity of talc affect its industrial applications. The talc rock from the Regal Mine in southwest Montana is some of the purest in the world, almost white in color. The boulder-sized rocks are drilled and blasted at the open-pit mine site, then hauled about 10 miles by large trucks to the mill, where they are processed into powder. For every 10 tons of rock, there is 1 ton of ore.

I visited and toured Barretts with John Parks, the Regional Health and Safety Manager. He showed me several types of milling processes: the ball bearing machine, the centrifugal force machine, and the solution machine.

When talc is brought in from the mine, it is dry or wet milled. The dry milling is relatively simple. The rock is put in large, cylindrical machines that use centrifugal force or baseball-size bearings to separate the odd minerals and the talc. The talc is lighter in weight, so it rises to the top of the heavier minerals. The talc is removed, run through crushers and machines that grind it to a fine powder, then bagged into 50-, 1,000- or 3,000-pound bags, depending on where it's going. Paint companies buy the 3,000-pound bags, while pharmaceutical companies buy the smaller bags

continued on next page

Talc *from page 41*

Wet milling uses a solution to separate the talc from the impurities. It is put in vats that have horizontal rotating paddles, similar to a paddlewheel on a ship. When the talc bubbles to the top, these paddles skim it off, like skimming cream off milk, and the froth goes into a slurry solution to be run through a hydrator.

The hydrator looks like a huge, vertical accordion with ribs and tubes running in and out of it. When this machine is full of the slurry, it closes and squeezes 90 percent of the water out of the solution. Then the hydrator opens and drops the damp talc which feels like wet chalk, onto a belt, which conveys it to a drying room. From there it is sent to what looks like a milking machine. A suction arm lifts sacks and places them on spouts. When a given weight is obtained, the bags are dropped upright and sent to a machine that seals them and sends them to be stacked on a pallet for shipping.

In a control room, computers monitor all the machines. One of the computers looks like a seismograph. The lines, vertical scribbles, are different colors for the different machines. The slightest deviation sets off an alarm and a person goes to the site to determine the problem.

Outside in the yard, there are piles of different grades of rocks 12 to 15 feet high. No talc is thrown away, it is just milled several times in different processes to have the impurities removed. Its softness, chemical inertness, whiteness, and affinity for organic chemicals make it good for industrial use.

The paper industry uses talc as filler and coating for its products. The ceramic industry uses talc for the shine and conductivity in dinnerware, tiles, porcelain, and electrical insulation. In paint, it helps control glossiness, improves durability, and fights rust. Talc also adds pigment control and stability to paint and coating.

In plastics, it gives stability and improves the ability to resist chemical and heat forces. Talc is used in electrical insulators to help lower energy waste in electrical devices. Talc, with its high heat resistance and bonding power, makes automobile hoses less permeable and gives rubber its bounce.

It is used in animal feed to help stop moisture from entering or leaving and to reduce the bacteria in feed troughs.

Talc is used in antacids, body soap, and detergent as filler. Pills are coated with talc to keep moisture out of them. Gymnasts and bowlers use it to keep

continued on page 44

Talc *from page 42*

their hands dry when gripping equipment. Other uses are in pencils, putties, countertops, flooring, asphalt shingles, foam packaging, candy, insecticide carriers, caulks, sealants, and baby and body powder.

Talc has historically been thought to be a health hazard if used in large amounts on the body. This has not been found to be true. It would take more talc than the average person uses in his lifetime to do harm. Instead, the mining and milling of talc has been the major hazard. Talc particles float in the air and workers inhale it, yet, talc has not been proved to cause lung cancer in mine and factory workers. Air quality is monitored at all times by the health and safety manager. Talc with asbestos fibers is mined only for research and study specimens. None of this talc is used in industry, domestically, or in pharmaceuticals.

Talc is soft and easily carved into beautiful forms. Some of the recorded history of decorative talc comes from the Lewis & Clark journals in 1803. When the explorers met the Shoshone Indians in Southwest Montana, they were offered a peace pipe to smoke. According to their journals, "This pipe was made of a dense semitransparent green stone, very highly polished, about 2 ½ inches long and of an oval figure, the bowl being in the same direction with the stem."

Talc can be carved using simple home tools: a pipe for making a cylinder, a knife, a small saw, files to smooth off corners and bumps, and steel wool for the final polish. When the project is complete, rubbing the object with denim or corduroy makes it shine like marble.

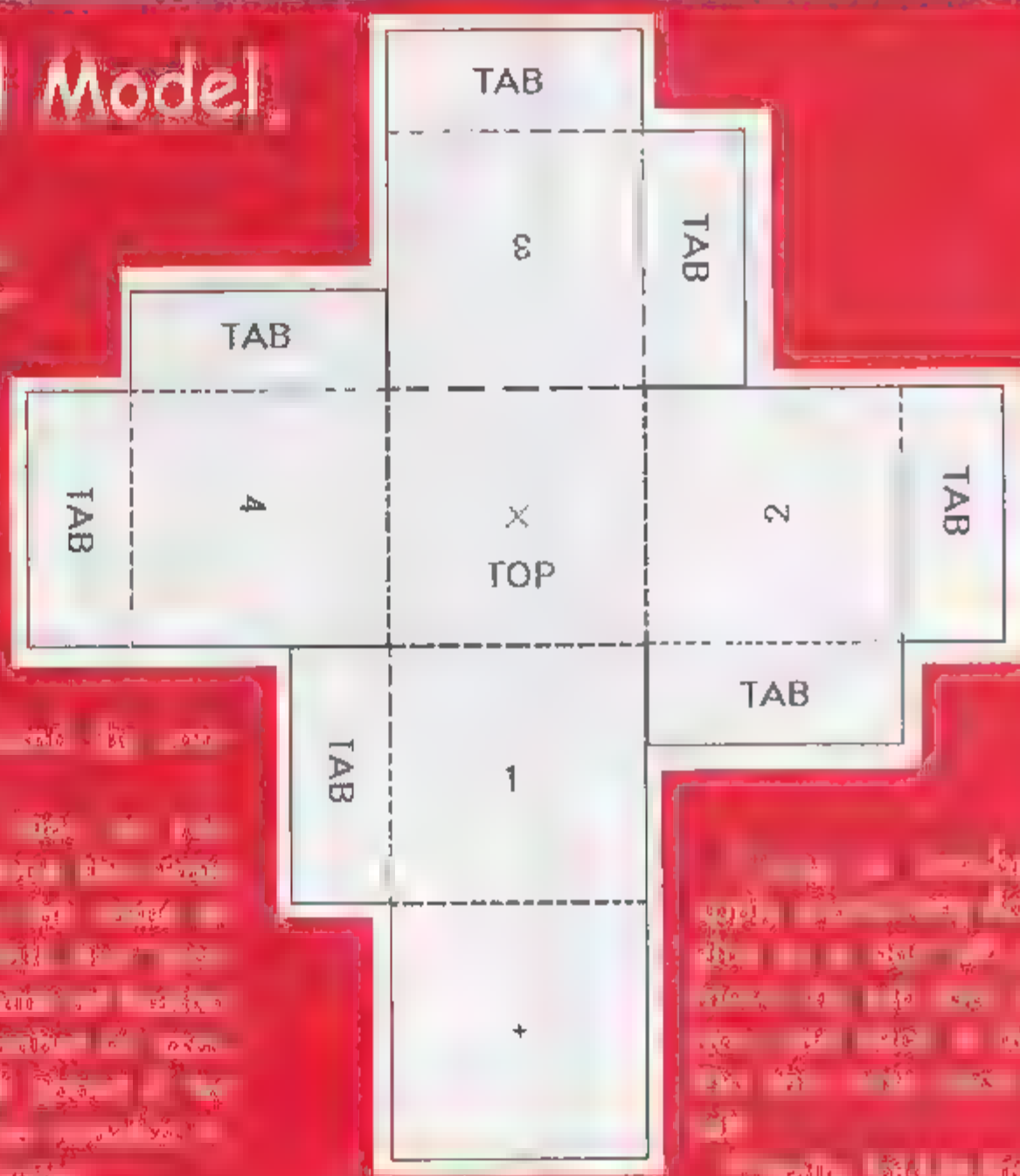
Hunters can use powdered talc to tell wind direction. Scented powder cannot be used, as animals will smell it. A person can grind his own talc powder by obtaining a rock, filing or sawing it, and saving all the particles in a small, clean container.

This mineral can be obtained by going to a mill and asking for a sample. When my group finished our tour, Mr. Parks allowed us to drive around back and pick up several of the rocks for our use. Rock shops also carry it for decorative purposes and for carving. The Web sites www.sculptor.org/Stone/Soapstone and www.sandyclime.com are two of the best for finding and obtaining talc for personal use, carving and sculpting.

Talc is a different kind of rock. There are no pretty crystals, no geodes, and no dramatic colors, but you'll find it almost everywhere you look. Talc is not your everyday rock in the park.

ROCK & GEM

Make A Crystal Model Part I



GLOSSARY Use your dictionary to look up other words you don't understand.

axis: a straight line with respect to which a body or figure is symmetrical

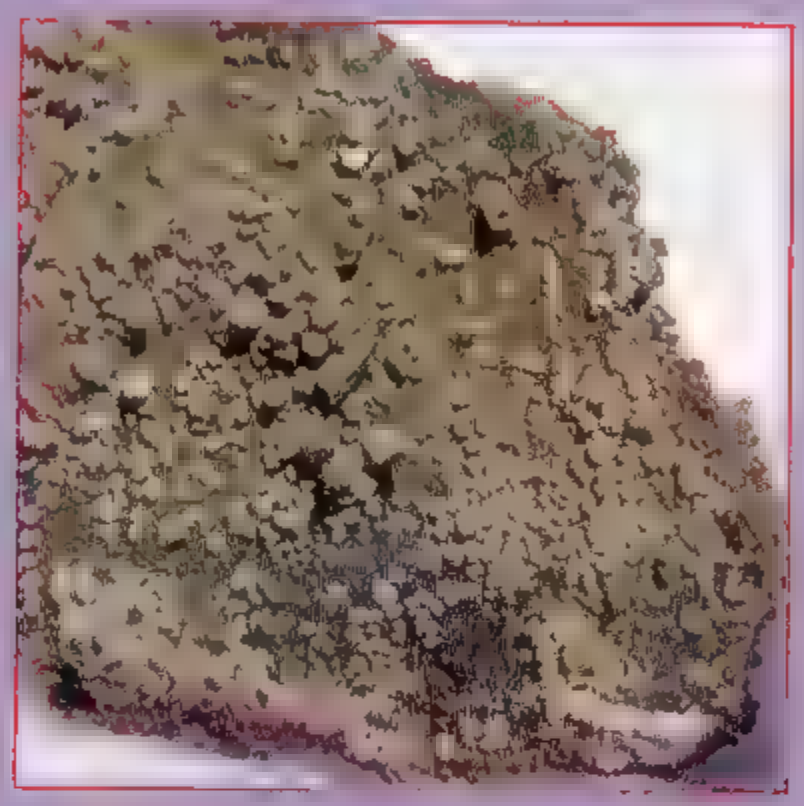
sphere: a solid that is bounded by a surface consisting of all points at a given distance from a point constituting its center; a globular body; ball

symmetry: correspondence in size, shape, and relative position of parts on opposite sides of a dividing line

KIDS

by Steve Voynick

Pyromorphite



Pyromorphite what can that mean in American English? We know *pseudomorphs* mimic the shape of some other minerals' crystals, so *-morph* must mean shape. I know that *pyrotechnics* is another word for *fireworks*, so *pyro-* must mean *fire*. Geologists say that the *-ite* suffix for mineral names comes from the ancient Greek word *lithos*, which means *stone*. I think we can put that together and say that *pyromorphite* means "fire-changes-my-shape stone." It probably refers to the fact that when pyromorphite is heated under the blowpipe, it changes shape, sometimes looking like worms.

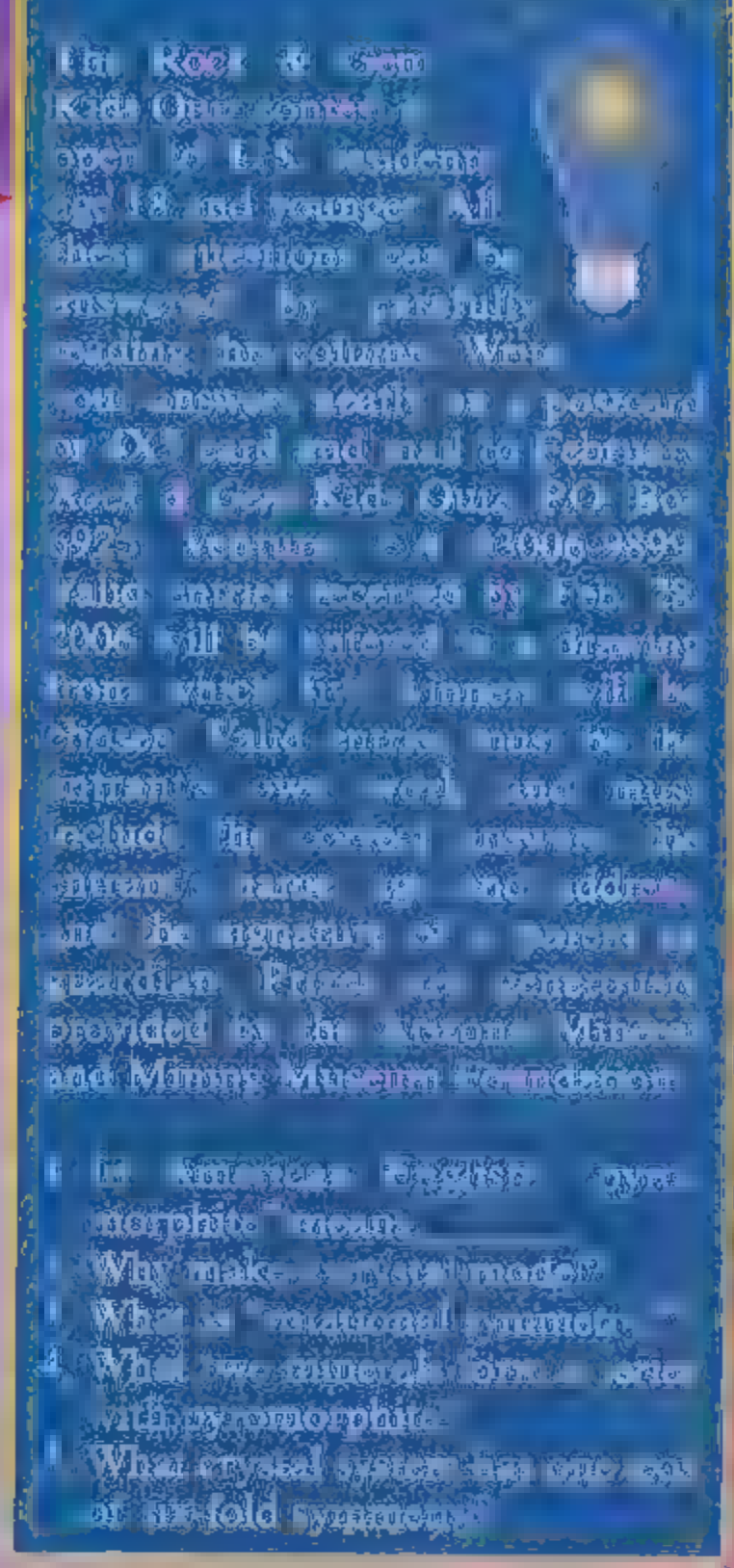
Pyromorphite (lead phosphate chloride) forms a series with mimetite (lead arsenate chloride) and vanadinite (lead vanadate chloride). All three members form nice hexagonal crystals that are often hoppered (hollow on top), and they may all have similar colors.

In the early days of mining in Germany, they were lumped together into the categories "brown lead ore" or "green lead ore." It is very difficult to tell which member of this series you have just dug up unless you have someone do a chemical analysis or blowpipe test for you. Pyromorphite seems to be the rarest and costliest member of the series, at least at the rock shows I go to.

Pyromorphite was identified chemically in 1784 and given its name by J.F.L. Hausmann in 1813. In the early part of the 20th century, wonderful pyromorphite crystal groups were found in large quantities at the Bunker Hill Mine near Kellogg, Idaho, and they were smelted as lead ore. I wish I could have bought a boxcar full of that ore and stashed it away!

Pyromorphite crystals are often bright green, yellow or brown, with a resinous luster. The Mohs hardness of pyromorphite is about 3 or 4. 💎

Rock & Gem Kids Quiz



FIELD TRIP

Minnesota Cold-Water Agates

Exploring Gravel Bars Along the Zumbro River

Story and Photos by Kennth H. Rohn

This blue-gray cold-water agate shines with a natural polish.

Careful and thorough preparation of any field trip is conducive to a successful adventure. A good hat or cap to protect us from the sun, plus comfortable footwear and sunglasses should top the list of essentials. A rock bag or pouch is also important, particularly if we have to walk any distance from our vehicle. A list is a good thing to make up. This way, when you check everything off, you'll be certain that you have the things that you need when you get there

This cold-water shows a pattern of bands, though they are not as pronounced as those in Lake Superior agates.

This Zumbro River agate has a bubbly appearance and a botryoidal effect at the tip.

When I traveled to the Zumbro River in southeastern Minnesota recently, I was excited. I had been thinking about this trip for a long time, but something always seemed to come up to interfere with my plans.

Minnesota is beautiful in July. In the north, the forests and meadows are a multitude of shades of green in sharp contrast with the deep blue lakes. Farther south, in the fertile bottomlands adjacent to the Mississippi River, the corn stands taller than most men. Some fields stretch to the horizon and look like a green sea. It's magnificent.

The object of my trip was to search out and collect a different species of agate than the popular Lake Superior type that dominates the northland. These agates were formed in the vast horizon of Decorah shale deposits that outcrop in this part of the state. Some call them "cold-water agates." I'm inclined to agree, because they were formed in a much different environment than the Superior type. They certainly must have had to originate by the process of hydrothermal activity, that is, the liquefaction of quartz minerals in water. Quite possibly, this slurry was not as hot as that which formed Lake Superior agates, but hot enough to dissolve and hold minerals in solution. Scale formation in a teakettle is a good example of this type of mineralization.

Cold-water agates were formed in sedimentary rock, which is the main constituent of shale. Shale was formed in a number of different ways. Decorah shale came into existence by the settling of aqueous solutions in a shallow sea over millions of years. I would assume that volcanic ash played a large part in the composition of this sediment. Over time, these deposits built up in layers that were thousands of feet thick in places. That this area of Minnesota was the bottom of a freshwater sea can be substantiated by the fact that invertebrate marine fossils have been found in number wherever the shale outcrops or has been disturbed by some sort of excavation, as in highway construction.

This is my theory on the subject of how cold-water agates were formed: Probably sometime after the formation of this vast, deep layer of sedimentary rock, cryptocrystalline quartz (chalcedony) in solution found its way into voids and pockets in this rock. Trace amounts of other minerals, which had a good deal to do with coloration, got into these voids, as well. These solutions eventually filled the voids and solidified into the finished agates.

Nature has produced specimens of chalcedony that man cannot duplicate for its genius of design. Except for their chemical composition, no two specimens of any agate are ever alike. This includes the cold-water type. They may look similar, but like human fingerprints, they are never quite exactly the same.

Over the untold thousands of millennia that followed, the agonizingly slow process of erosion took place. Eventually, the sea dried up and disappeared. Upheavals and movements of the Earth's crust forced some of these Decorah deposits near or to the surface. Continuing over possibly hundreds of thousands of centuries, more erosion took place. Shale, being much softer than chalcedony, eventually disintegrated in places, leaving behind deposits of cold-water agates and other hard minerals associated with them, such as jasper and flint.

Rivers were formed when the ice began to melt from the last of the great glaciers that ground their way south 100 centuries ago. Although very little evidence of glacial action can be found in southern Minnesota, it had a great influence on the land as we see it today.

More erosion took place as the boulders and smaller rocks that were too hard for the ice to crush were reduced in size by a natural tumbler. While on their way downstream, possibly millions of tons of rocks settled in gravel bars in the riverbeds. Many of them remain today. During low-water periods, these bars are quite prominent. The Zumbro River has a number of them.

continued on next page

This brown agate does not have the bubbly appearance that some of the others have.

Minnesota *from page 51*

The Zumbro River consists of north, middle and south forks, as well as numerous tributaries. I haven't followed it to its source, but it's quite long and cuts across the eastern portion of south-central Minnesota from east to west. The South Fork veers south to Zumbro Lake, quite a way south of the town of Mazeppa. To date I have only scratched the surface so to speak, by exploring a very short section of the North Fork.

I studied the Zumbro's North Fork route on my Minnesota atlas. I followed it upstream to what appears to be its source a bit southeast of Faribault, in Rice County. A rough estimate makes it 100 miles as the crow flies from this point to where it empties into the Mississippi. Taking into account that there are hundreds of oxbows and horseshoe curves in this river, I would guess the river's actual length to be perhaps 10 times that.

There are a good number of bridges that cross this river before it reaches the Mississippi; I counted 16. I would assume that the majority of these crossings do not have gravel bars adjacent to them, but it would be well worth checking a few of them out. Discovery is a large part of the excitement of the hunt.

It would take a good deal of time to explore even one of the forks in its entirety for potential collecting sites, but as I learned, the area of the Zumbro that I traveled and the gravel bars that I collected on proved very satisfactory.

Investigating the various forks of the river properly would require county maps. They are usually for sale at each county seat. These maps have much better detail than a regular road atlas and can be purchased for a reasonable price.

I had done some collecting along this river several years ago between the towns of Zumbrota and Mazeppa. During my last field trip in the area, I also managed to recover several marine fossils from the pretty yellow Decorah shale of a road cut near the town of Wanga, Minnesota. They included tiny clams, sponges and petrified algae.

When I arrived in the area on this trip, southern Minnesota was in the midst of a heat wave with temperatures reaching close to 100 degrees. The humidity, which hovered close to 75 percent, didn't help matters, either. Minnesota does get very hot and humid during the summer months, so it pays to be prepared. A sudden and unexpected rainshower often cools things down a bit. My cousin Joan has a saying that usually holds true: "Wait five minutes and the weather will change."

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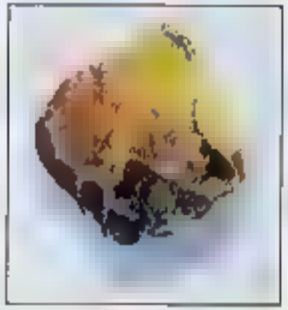
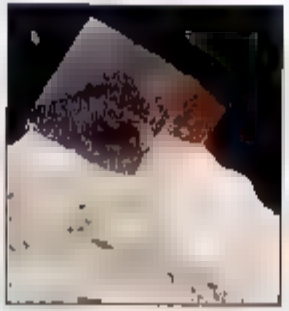
Hanksite
January

Amber
Feburary



Pyrite
March



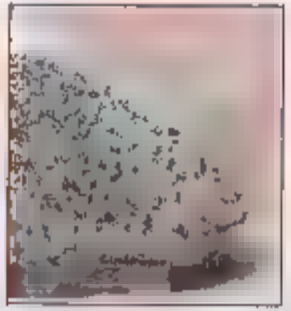
Cavansite
April

Apatite
May

Apophyllite
June

Halite
July

Cornetite
August



Wavellite
September

Crocoite
October

Hemimorphite
November

Ruby
December

Minnesota *from page 52*

My first stop was at Zumbrota. With a population of just under 2,500, it's a clean, friendly community where most everybody knows everybody else. The town has a beautiful park and campground. It also has an old covered bridge, which people traversed back in the days when things seemed to move a bit slower than they do today. It's a very photogenic and beautiful bridge and is worth stopping to see and take photos of.

The Zumbro River flows right through the edge of town. A casual investigation showed much private property and no possible collecting areas, so I drove on over to Mazeppa.

I would imagine that, if one were to locate any gravel pits near the several towns along the route and acquire the necessary permission to collect, many surprises would be in store. Agates and even invertebrate fossils could be found in some of them.

In this day and age discovering new collecting sites is getting difficult. No matter where one goes, landowners are reluctant to allow strangers onto their property and rightfully so. Thankfully, I've met some very accommodating people during my travels.

It's to our advantage to search out and locate waterways and areas that have a public access such as bridges, highway rights of way, and any land controlled by the federal government, particularly national forest and Bureau of Land Management (BLM) property. Every piece of property, no matter where we are, belongs to somebody or some organization. For our own protection, we as rockhounds must investigate thoroughly before entering any questionable site, no matter how inviting it may look.

If I remember correctly, a Minnesota statute allows public use of any watercourse that is considered navigable. This would mean rivers, creeks, and lakes. Since this state has a minimum of 10,000 lakes and who knows how many navigable rivers, there's a vast potential that has actually never been explored here. So if one can float a canoe, for instance, on a body of water, that water is considered navigable. The problem is getting to the water without trespassing. Also, supposedly 6 feet of shoreline is public domain. I've had some landowners dispute this in a heated manner with me on occasion, but that's another story. I might add that, in my experience, it never pays to argue with a landowner. We must assume that he or she is right and leave.

continued on next page

Minnesota *from page 57*

The water level in the lakes and streams in Minnesota (with a few exceptions where dams regulate it) is governed by the weather. Since there are no tides, as in the oceans, the level remains basically the same for much of the year, fluctuating a bit during wet and dry seasons. So we can bank on those 6 feet of shoreline being available.

No matter which direction you may be coming from, well-maintained highways will take you to the towns of Zumbrota and Mazeppa. Interstate 35 runs north and south, dissecting the eastern side of the state very close to the cold-water agate destination. Interstate 90 runs east and west through the southern portion of Minnesota. Other roads will take you there, as well.

Mazeppa, with a population of 722, is no more than six or seven hours from any point in the state. U.S. Highway 52 is an excellent freeway leading southeast from St. Paul. This will take you to Zumbrota.

A few miles south of Zumbrota, I took state Route 60 to Mazeppa. From there, I drove east on State Road 60 a short distance to the junction of County Road 7. Then I followed CR7 to the junction of County Road 77.

The bridge over the Zumbro River is in close proximity to this junction. As a matter of fact, I parked near the corner of CR77 (a gravel road) to be out of the way of traffic. There is ample shoulder and enough room to park safely on either road. It's approximately three miles on this route from the bridge to Mazeppa.

The first gravel bar I discovered is downstream (to the left going east on CR7) from the bridge. The fact that this area is a catch-and-release fishing access makes it an ideal location for us. Of course, if trout fishing is part of your itinerary, what better place to be?

Although I'm an avid fisherman, my mind was focused on agates at the moment. The first gravel bar is just a short way from the highway right of way. The tangle of tall grass and shrubs practically hid me as I made my way down to the water's edge.

I stood on the bar and admired this bounty before me. It's about 50 yards from the highway and composed of a wide mound of water-worn rocks. They're anywhere from pea size to boulder size. The majority of the rocks are very clean. This often helps me to identify the agates, but it took me a few minutes to orientate myself before I was able to find one.

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Minnesota Cold-Water Agates *from page 58*

These are possibly the strangest agates I have ever encountered. The majority of those that I collected look as though they had been aerated by high-pressure gasses. Many of the specimens I picked up look like bubbly masses with no particular pattern or configuration at all. Some have a botryoidal pattern. One is a very pretty blue-gray with white streaks through it. I wonder how it will look when sliced. I have an idea that the center is a solid mass of beautiful blue, gray and white agate

Another potato-size agate with a similar configuration as the first is chocolate brown throughout. It has that smooth, hard texture typical of all agates. I also picked up a few very nice specimens of red, purple and golden jasper.

An agate that shows great potential for cabochons fits nicely in the palm of my hand and is a pretty blue-gray with white areas in it. One end has been broken off, leaving a window. This window shows a swirl pattern with blue and gray streaks in it

In contrast to those mentioned above, I picked up a number of flat slabs of agate. These have a similar coloration, but they are smooth, without the bubbly effect. The one I'm studying is an inch thick and 3 inches wide by 4 inches long. It has a nice pattern of gray and dark brown bands in it. These bands are not as pronounced as those found in Lake Superior agates, but they do stand out. This particular specimen has an off-white crust as thin as a sheet of paper, and my guess is that it's common opal.

I checked the stones for fluorescence with my long-wave black light. Only three showed any change. One glowed a very pretty orange, another turned lavender, and the third one was a combination of lavender and orange with a much fainter response to the light. The other stones I collected that day show no activity at all under the light.

The first gravel bar is quite long and tapers off as the river makes a bend to the right some distance from the road. The next gravel bars are but a short way on CR7, east of the bridge. There's a two-rut road leading down to the river that is about 100 yards long. I would not recommend attempting it with a two-wheel-drive vehicle, although it was dry and hard when I was there

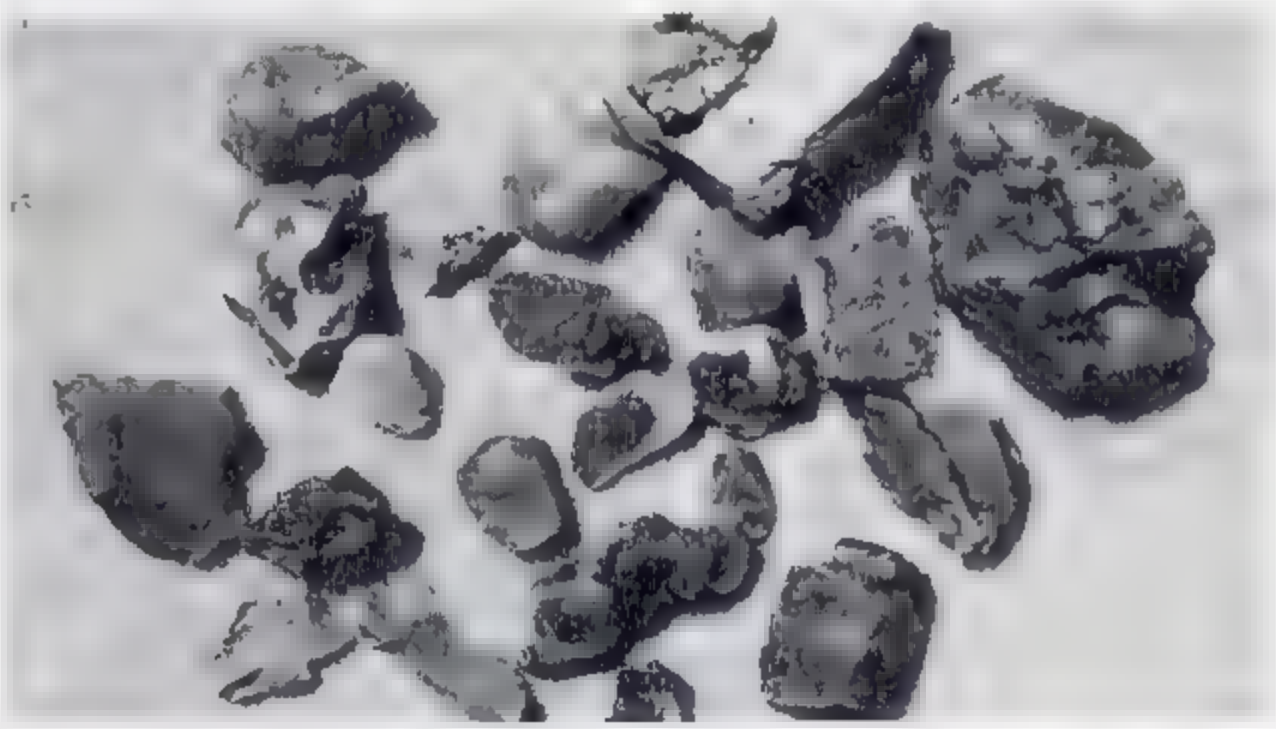
One gravel bar is partially overgrown with grass and weeds on the highway side of the river, but it, too, has potential. I collected some nice agates there. The gravel bar that attracted me the most was on the other side of the stream.

When I was there in July, the water was low, although the current is rather swift. It's not swift enough to be what one would call dangerous, but I would keep a close watch on children when crossing over.

The expanse of water I crossed at the two-rut road is no more than 30 feet wide. The water was below my knees at the deepest place, which had a sandy bottom. I took my two-man rubber raft with me, but it turned out to be more work crossing this way than just wading across. The boat came in handy for carrying my loaded rock bag, camera equipment, and drinking water when wading across, though.

While I was at this bar, I discovered yet another one farther upstream, so there's plenty of potential for collecting here. One way to identify the sites from the highway is the yellow signs indicating fishing access points. There's one at the bridge and another at the second site mentioned above

I had a great time searching gravel bars on the Zumbro River and discovered a strangely different type of agate that originated in what was once the bottom of a vast inland sea millions of years ago.



I collected agates in a variety of shapes and shades on gravel bars in Minnesota's Zumbro River

FIELD TRIP

Collectibles in Sediments

Cone-in-Cone Structures Near Erie, Pennsylvania

Story and Photos by Robert Beard

Sediments are typically rather boring for mineral collectors. You can sometimes find fossils, but more often, sediments are barren of collectible minerals. Nowhere may this seem truer than in the sediments of northwestern Pennsylvania near the coastline of Lake Erie.

These sediments consist of a thick series of Devonian- and Mississippian-age formations that strike roughly northeast-southwest and dip gently to the southeast. The units get progressively younger as you go upward through the section when heading inland from Lake Erie. Although much of the area appears relatively flat from the highway, many of the stream valleys are deeply incised. This results in a distinct pattern on geologic maps of the area in which the older rocks are within the streambeds and show up as dendritic branches that come together as the streams flow into Lake Erie.

The dip to the southeast is often very slight and the beds in many places are nearly horizontal. This leads to some very scenic stream valleys around Erie, many of which are similar to a series of broad, flat steps. It is often easy to walk upstream, although during high water you will get your feet wet.

Although the streams, with their walls of fine-grained sediments, appear barren at first, there are many interesting minerals to collect in the streambeds that empty into Lake Erie. I have found several slabs with fossil shells and trace fossils, and some of the granitic and metamorphic rocks that have washed down the stream can also be interesting.

However, perhaps the most interesting collectible feature of these sediments is not a mineral or fossil, but rather a unique sedimentary feature known as a cone-in-cone structure. Interestingly, none of the mineral guidebooks that I have on Pennsylvania localities discuss these features, so one may consider them new territory for many collectors.

Cone-in-cone is a distinctive sedimentary feature that forms during the deposition of shales and other sediments as a result of flow and pressure. The sediments form cones that are superimposed on one another as the rocks are being deposited, and the resulting pattern consists of edges on the cones that are ridged and grooved. The cones are nearly always perpendicular to bedding

The mouths of the cones are often not circular and sometimes form polygons with rounded corners.

The rocks with cone-in-cone structures are generally easy to spot, as their surfaces are covered with deep pockmarks. Breaking them often reveals a striking pattern of cone-in-cone structures.

The cones can vary considerably in size and shape, and the mouth of the cone sometimes flares to give the appearance of a small trumpet. The cement that bonds the sedimentary particles together is usually calcite or gypsum. As the rocks solidify and are subjected to pressure, the cones are subjected to minute fracturing and the breakages overlap, resulting in the ribbed and scaly appearance of many of the cone surfaces. Cone-in-cone structures are found in sedimentary rocks around the world, and have been found in gypsum, siderite, and hard coal, as well as shale.

A friend of mine showed me a rock with these structures and I was very surprised by its appearance. It looked like the rock was made of a series of cones. He had found it along Four Mile Creek near Erie, Pennsylvania. Four Mile Creek is one of the series of "mile" creeks that drain into Lake Erie. The other nearby mile creeks included Six Mile, Eight Mile, and Twelve Mile creeks; the numbers increase as you progress to the northeast of Erie, which is useful for knowing their general area. I later went to the area of Four Mile Creek where my friend said he found it, but was not successful in finding any pieces.

A few years later, I was in the same area with a different friend. I had been looking at the ground along Four Mile Creek for some time when he said "Wow, what is this rock?" He had found a small outcrop with abundant small cone-in-cone structures. He was not a geologist or even a rock collector, but even he was struck by the unusual character of this rock. I was surprised that the rock was actually within the outcrop. I had a hammer and chisel and was able to easily cut out a small section for my collection. Apparently, my mistake had been in looking for loose rocks; I should have been looking in the outcrops along the creek bank.

Elk Creek: Elk Creek is a major drainage in the Erie area, and is about 15 miles southwest of the city of Erie. I reasoned that most of the beds along Elk Creek would be roughly horizontal, so most places along the creek would likely have similar geology and have potential for good cone-in-cone structures.

In order to find a collecting site, I had to locate an area that had creek access. The banks of Elk Creek, like those of many of the other creeks, are very steep. Using the *Pennsylvania Gazetteer* (Delorme), I reviewed the accessible areas of Elk Creek. I was coming from Erie and selected the area just south of Interstate 90

The first place I attempted to access the creek was far too steep, and it did not look like it had the right types of outcrops. The next place I selected was where a covered bridge crossed Elk Creek. I reasoned that it should not be difficult to get into the creek near such a bridge

The covered bridge, which is on Gudgeonville Road, is clearly marked in the *Gazetteer*. I parked on the west side of bridge and climbed down into Elk Creek. It was fairly steep, but at least it was a short climb. There was a large island with lots of rocks south of the bridge, and I thought I could likely find some nice cone-in-cone pieces there.

The cone-in-cone features are perpendicular to bedding, and the sides of the cones often have an intricate rippled pattern.

I later showed this same piece to another geologist who lived in the area She said that she had seen plenty of them along Elk Creek near where she lived, and indicated that the structures were quite common there. I thought this was very useful information, as I wanted to get additional specimens and I was not having any luck in the areas in which I was searching.

Since I had not found any specimens of cone-in-cone structures along any of the mile creeks, I decided to take a brief look at some of the rocks in the area of

River collecting has many advantages, one of which is that rivers are often accessible to fishermen and hikers. The banks of some sections of Elk Creek in this area were on private residential properties, and I did not want to disturb any of the owners. If anyone saw me, they would likely think I was fishing or looking for fishing spots.

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The cone-in-cones can often be separated from the rest of the rock.

Elk Creek is a very beautiful creek and was very shallow. I soon came across an area of small rapids near the island, and continued to watch the shorelines for signs of cone-in-cone rocks. I soon found a large block about 8 inches on each side that had distinct round depressions on one of its sides. The depressions indicated that this was a cone-in-cone piece. It was quite large, and I decided to keep it intact instead of smashing it to expose fresh surfaces. I was not sure whether I would find more pieces.

Elk Creek then took an abrupt turn to the west. The southern bank of the creek in this area is a sheer wall that is over 100 feet high, but the northern bank does not have a similar wall. The rocks along the southern bank have horizontal outcrops, and I walked across the creek to look at these outcrops.

I noticed that, although the bedding in the outcrops was horizontal, it was not uniform. Some of the sediments had a distinct pattern of vertical, linear features perpendicular to the bedding. I was able to peel a large section of this out with the pick end of my hammer. It only took a light hit with my hammer to break this large, flat piece apart, as it was only about 2 inches thick. It was loaded with cone-in-cone structures and was quite striking. The bottom part of the rock had slight band of iron staining, which added to color to the rock.

The cone-in-cone structures are extremely detailed when viewed with a hand lens or up close with your eyes, especially if you are extremely nearsighted like I am. In this piece, the cones at the bottom of the rock are flared open like a cornucopia, in a layer about ¾ inch thick. Above this is a layer of cones.

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They may resemble a jawbone with fossil teeth, but they are just cone-in-cone structures

The cones are about 1 inch long, and ¼ inch to ½ inch wide. The cones are wider at the bottom of the rock and point upward. It seems that, as deposition occurred and the pressure became greater, the sediments pushed downward and caused the cones to flare outward. Above the cones were a couple of very thin beds, only ¼ inch thick that had very small cone structures.

It was easy to see how some people could consider these pseudo fossils. The elongated sections of the cones strongly resemble belemnite fossils, but I have never seen belemnites with a ridged surface. If one carefully broke out the cones, they could also resemble teeth, but fossil teeth are generally much harder than shale. They also resemble trace fossils, but their abundance and regular pattern would tend to rule out consideration as traces of living organisms when you look at them in detail.

Once I found the area of the outcrops, there was practically an unlimited amount of material for collecting. It was simply a matter of collecting the best pieces and deciding what I wanted to carry out. There are undoubtedly many other sections along Elk Creek and nearby drainages with similar outcrops with cone-in-cone structures, and I suspect that some of them may have some very long cones.

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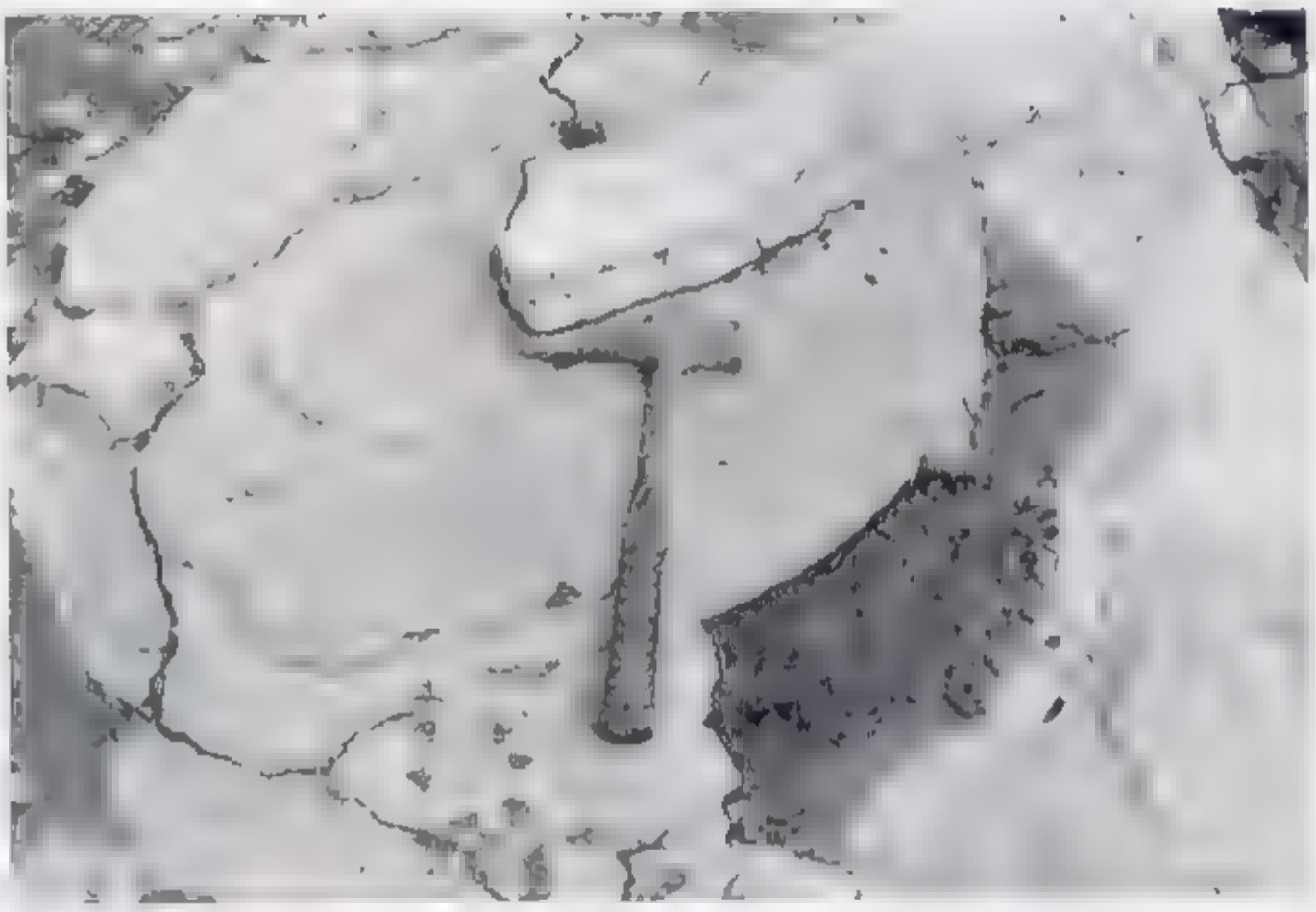


Large, flat pieces can easily be extracted from the outcrops and broken apart to reveal the cone-in-cone structures.

It was hard to beat this area for scenery and ease of collecting. The Erie area is beautiful, especially in late spring, summer and fall, but winter is definitely not a good time for collecting here. High water will undoubtedly inhibit streambed collecting, so it is certainly best to collect when the water levels are known to be reasonable.

I later reviewed the geologic map and found that the area in which I had collected was mapped as the Devonian-age Girard Shale. This information was in *Groundwater Resources of Erie County, Pennsylvania*, Water Resource Report 62 (Pennsylvania Geological Survey, 1987). The Girard Shale is described in *Engineering Characteristics of the Rocks of Pennsylvania* (Environmental Geology Report 1, Pennsylvania Geological Survey, 1982) as a light- to medium-gray, very fine-grained shale, and this report notes that cone-in-cone structures are present.

Both of these are recent publications and can be ordered from the Pennsylvania Geological Survey (717/787-2869, www.dcnr.state.pa.us). Interestingly, *Engineering Characteristics* is the only reference I have found that mentions the cone-in-cone structures; I have not seen these structures discussed in any mineral collecting guides for Pennsylvania.

To get to this site, take Interstate 90 to Exit 16 and go south on state Route 98, which is also known as Avonia Road. Turn right (west) on Sterrettania Road, and then turn left (south) on Franklin Road, which ends at Beckman Road. Turn right (west) on Beckman Road and then turn left (south) on Gudgeonville Road.

Follow Gudgeonville Road to the covered bridge and park on the right shoulder of the road next to the covered bridge. You can climb down into Elk Creek at this point. The sides can be a little steep, and you must be careful to avoid the private property near the bridge, as it is posted. However, there should be no problem with walking along Elk Creek.

The site is on the USGS 7.5 minute Albion, Pennsylvania, quadrangle. The latitude and longitude of the parking area is 41.9819°N, 80.2669°W. The outcrop with the cone-in-cone structures is at 41.9812°N, 80.2657°W. These are taken directly from the topographic map from www.topozone.com.

I believe that this site is but one of many locations along Elk Creek and nearby creeks that will produce good cone-in-cone samples. I suspect that good samples may also be found where Elk Creek empties into Lake Erie. The key to collecting in this area is finding an accessible site; fortunately, access appears to be generally good. However, as with any river collecting, be very careful about collecting if the water is high or if conditions indicate that the water may present any danger. If this site is inaccessible due to high water, I would check other sites to the northwest as Elk Creek continues its descent into Lake Erie. You will likely find additional sites with cone-in-cone structures with a little bit of luck and diligent searching.

Rock Science

by Steve Voynick

Classifying Minerals

Mineral collectors are familiar with mineral-classification numbers—most often a "Dana number" or a "Strunz number"—that appear in mineralogical descriptions or on specimen labels. As an example, the familiar mineral galena, or lead sulfide (PbS), has the Dana number 2.8.1.1 and the Strunz number II/C.15-40.

Here's what those numbers mean. The Dana number 2.8.1.1 first identifies galena as a sulfide (2). The subclassification (8) next identifies it by the general formula $A_mB_nX_p$, in which A and B are metal cations and X is sulfur and the ratio of m+n:x is 1:1, a ratio that is reflected in galena's single lead cation and single sulfur anion. Galena is then assigned to its own group (1) as the first member (1).

The Strunz number II/C.15-40 first identifies galena as a sulfide or sulfosalt (II). The subclassification C next identifies it as a metal sulfide in which the ratio of the metal to sulfur (or selenium or tellurium) is 1:1. Finally, galena is a member of the galenite group (15) with the species number 40.

To complicate matters, Hey's Mineral Index assigns galena a classification number of 3.6.5. Multiple mineral-classification systems are necessary because no single classification system can serve all classification, study and research purposes.

The first mineral-classification systems were based on mineral uses and such physical properties as color, hardness, fusibility, and general morphology. A typical system of the late 1700s, a time when knowledge of chemistry and crystal structure was only rudimentary, was that of German mineralogist Abraham Gottlob Werner (1749-1817). Werner's system employed seven criteria: color, crystal form, crystal habit, cleavage, luster, streak, and hardness.

But by 1800, advances in chemistry had made chemical composition the main classification criterion. Shortly thereafter, growing knowledge of structural and mathematical crystallography made structure an important consideration. But although many prominent mineralogists, chemists and crystallographers began incorporating chemistry and structure into their own mineral-classification systems, none gained broad acceptance.

Then in 1837, a young, Yale-educated, American researcher named James Dwight Dana (1813-95) published *System of Mineralogy*. This 580-page classification system, which combined original material with concepts drawn from earlier works, quickly became a widely recognized reference. Dana initially based his *System* on preexisting botanical and zoological classification systems, but revised it in 1854 to one based on mineral chemistry and, to a lesser degree, on structure, an approach still used today. In 1892, Dana's son Edward Salisbury Dana (1849-1935) published the revised sixth edition of Dana's *System*, which became the world's standard reference work on descriptive mineralogy. Today, the reworked Dana system recognizes 87 primary classes of minerals.

When James Dwight Dana first published his *System*, science recognized only 352 mineral species. But within a century, this number had soared to more than 1,500. Mineralogists would subsequently update the Dana system and devise new systems to better classify the rapidly growing number of minerals. One, published in 1941 as *Mineralogische Tabellen*, was arranged by the German mineralogist Dr. Karl Hugo Strunz (1910-85). The Strunz system, also commonly used today, is based on such anion groups as carbonates, sulfates and phosphates, and includes 10 primary compositional classes.

The continuing discovery of even more minerals, many with complex chemistries that do not assimilate easily into existing classification systems, creates the need for new systems such as Hey's Mineral Index, published in 1993 by Dr. Andrew M. Clark of the British Museum in London. Hey's Mineral Index, named for the eminent British mineralogist Max H. Hey (1904-84), recognizes 32 primary mineral groups based on chemistry and structure and arranged by order of elemental activity.

Today, the Dana and Strunz systems are probably the most widely used mineral-classification systems, at least among serious collectors. But the number of alternative systems continues to grow. There are now more than 4,400 minerals, with dozens of new species being recognized each year. As establishing and understanding mineralogical associations becomes ever more complex, mineralogists will continue to devise new classification systems to better serve specialized research and study purposes.

Silver Treasures of Kongsberg

Unique Specimens from Famous Norwegian Mines

The tour of the King's Mine begins with a train ride into the depths of the hills at Saggrenda.

Story by Kiera Tara O'Brien

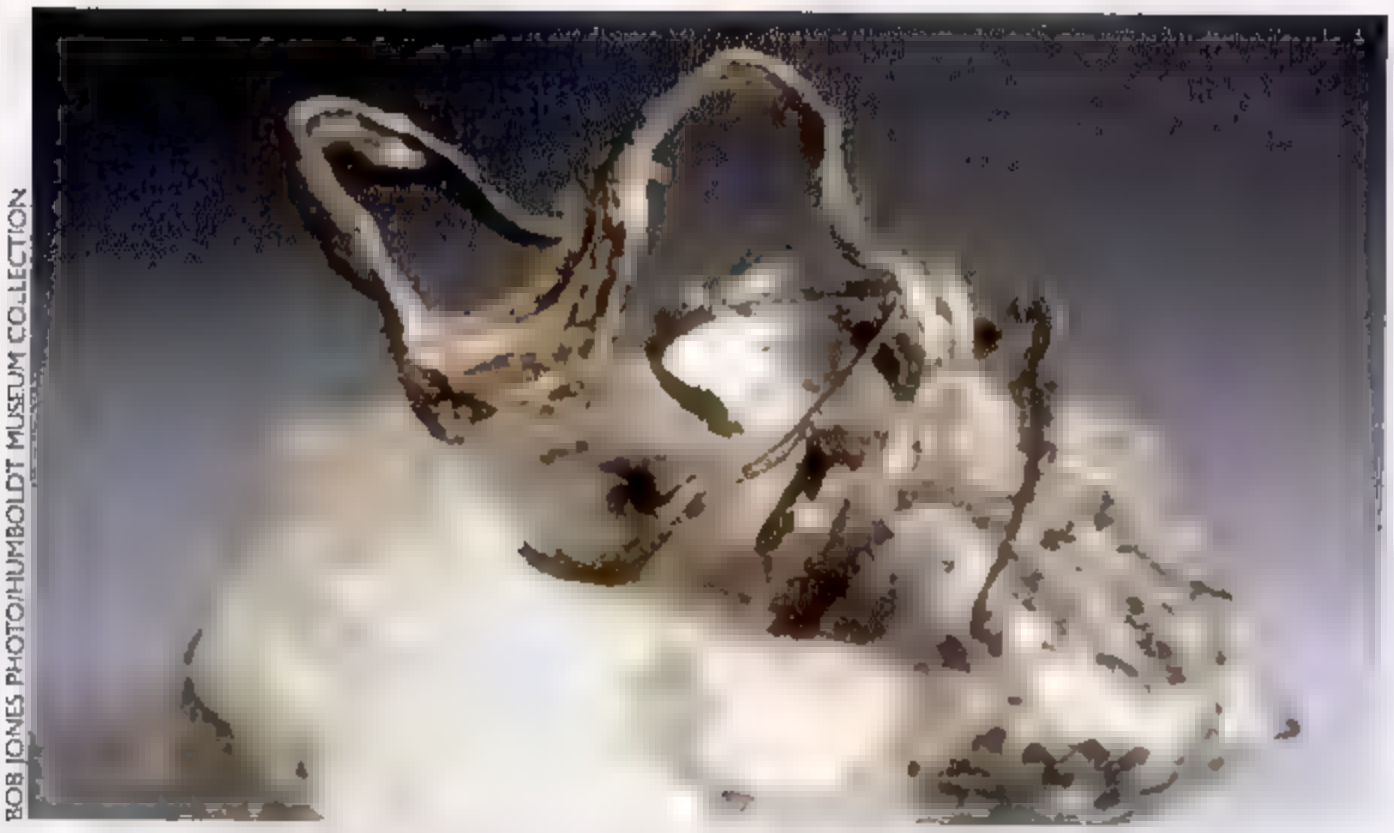
In the late 1700s, the second largest settlement in Norway was the booming mining town of Kongsberg. Located inland an hour's drive from the capital city of Oslo, this town has preserved much of its mining landscape for culture-hungry tourists to admire, including the nation's first permanent mine. Trials pits, shaft openings, slag heaps, artificial lakes, industrial installations, architecture, and an extensive network of underground tunnels and galleries adorn the area, which was declared a protected national treasure by King Harald and Queen Sonja in May 2003.

Industry and commerce in the late 18th- to 19th-century city was concentrated around the flourishing silver mines. The city and its mining industry carried such weight for the economy that Norway actually considered making it the national capital once upon a time. It was eventually beaten out by the more accessible port city of Oslo.

Before it assumed this illustrious position as one of Norway's, and indeed Scandinavia's, chief cities of the time, the area around Kongsberg was nothing more than farmland and cattle pastures. One afternoon in 1623, two young cowherds made a remarkable discovery of pure natural silver in the hills of Saggrenda. More correctly, one of their bovine charges casually unearthed a vein of silver by scraping away a large patch of moss from the ground in its search for tasty grasses and shrubs.

Like the cow that kicked over the lamp and burned down Chicago, this bull set Norway ablaze with silver fever. At first, the landowners tried to keep the vein a secret, smelting and selling off the precious metals, but inquiring officials forced them to confess where their silver source was located. At the time, Norway was under Danish rule. The mines were officially declared to be the possession of King Christian IV in Copenhagen, and the silver flowed south to the court of the Dano-Norwegian king

Dramatic Norwegian silvers resembling bonsai trees are particularly praised for their natural beauty and rarity.



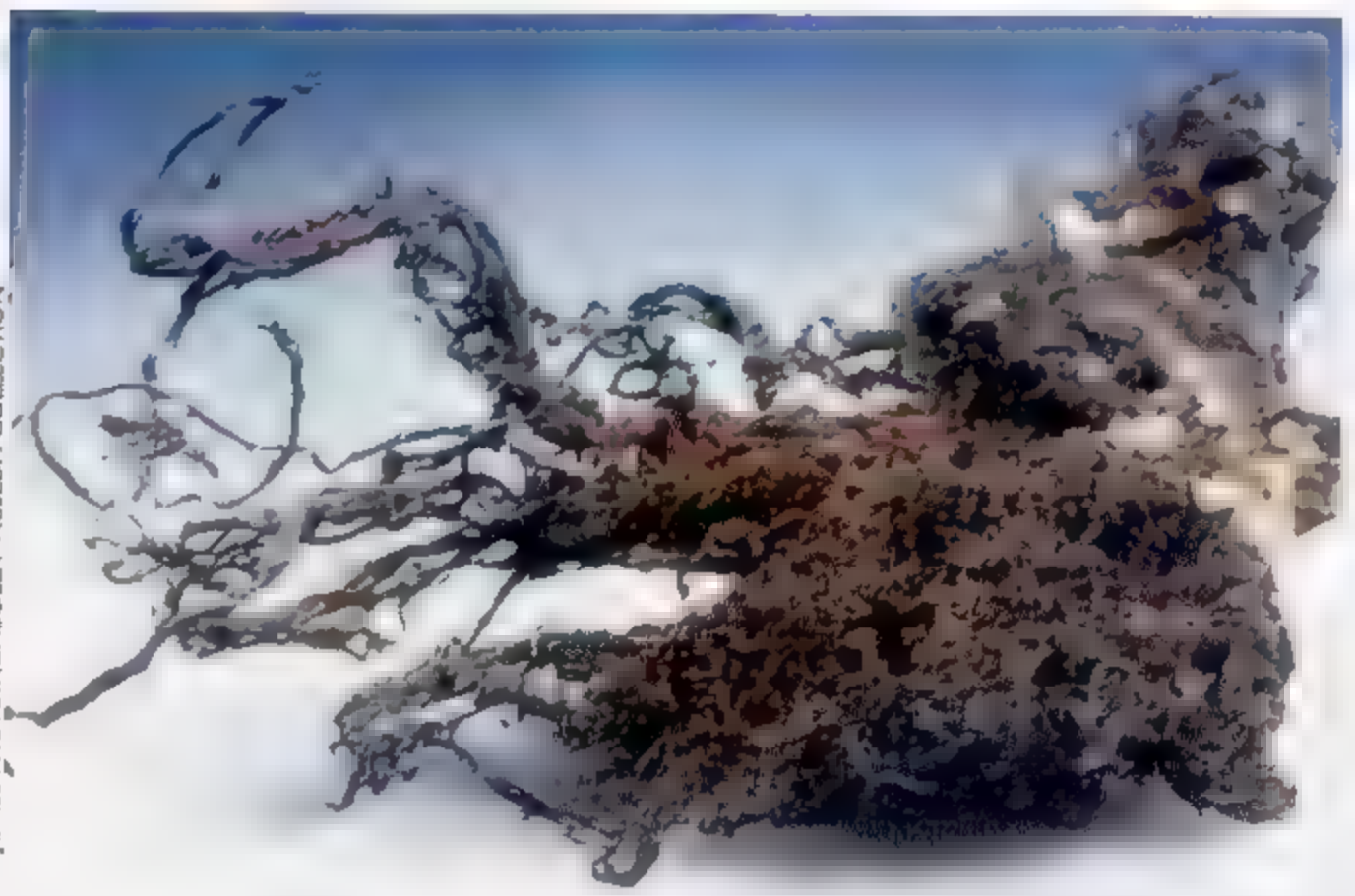
BOB JONES PHOTO/HUMBOLDT MUSEUM COLLECTION

Delicate, snaking silvers from Kongsberg are often found attached to quartz bases.

Almost immediately, the newly established Kongsberg Silver Mining Co. opened full-blown mining operations on a site near Saggrenda on Oct. 18, 1623. The town of Kongsberg, or Konigs-Bierg as it was known then, was founded by Christian IV during a visit to the mines the following year

Soon after establishment, the mining enterprise at Kongsberg became the largest and most profitable venture in Norwegian mining history. In the mid-1700s, the aggregate earnings of silver mining in Kongsberg accounted for roughly 20 percent of the government budget and the mining company employed more than 4,000 people. By the time mining operations were discontinued in 1958, a total of 1,350,000 kilograms of pure silver (and a substantial amount of copper) had been unearthed. Various "wire" specimens of unearthly design are still being uncovered today.

In order to keep a tight grasp on his silver source, Christian IV began the construction of a national highway stretching from Kongsberg to Bragernes (the modern town of Drammen). Known as Sølvveien, the Silver Highway, it brought German mining engineers to the district, as well as all the most up-to-date technological advancements. Silver poured out of the region, transported along the Sølvveien through Drammen to Oslo and finally to the Danish nobles across the sea. With such wealth and technology amassing in the district, life was never quite the same for local farmers, many of whom became involved in producing and transporting timber and other natural resources needed for the mines.



BOB JONES PHOTO/HUMBOLDT MUSEUM COLLECTION

Some large silver specimens from Kongsberg formed in rather odd shapes, such as this tangled yarn-style piece.

ALL THE KING'S SILVER

The Kongsberg region is geologically unique. Quite unlike many other silver mining districts, it contains almost no sulfides and loads of native silver, as well as some large aggregates of massive and wire silver. Filled with Precambrian rocks of mica and granite, the district extends about 30 kilometers from north to south and 10 kilometers east to west, and is estimated to be around 1.6 billion to 1.2 billion years old.

Rusty-colored zones with sulfides such as pyrite run along the length of the Kongsberg district. The early German miners called these zones "fahlbands." Only at the intersection of a fahlband and a calcite vein would miners find the prized silver pockets, and sometimes copper or cobalt if the zone was particularly rich in sulfides. Most of Kongsberg's grandest mines were located in the central area, where the two largest fahlbands were located

Young quartz veins also run through the Kongsberg mining area. Many primary minerals have been identified in this locality, such as pyrrhotite, galena, gypsum, marcasite, chalcopyrite, sphalerite, fluorite, pyrite, calcite, stilbite and gold. These specimens were mined irregularly between the 1600s and 1945. Some quartz samples uncovered recently in the region have been infused with the phantom outline of calcite and fluorite crystals, an interesting effect. More than 100 different mineral species have been located in Kongsberg since the closure of the mines, although the King Kong of them all will always be native silver.

Silver was the primary focus of interest from the early to final days of mining activities in the area. True to the trends of the time, from 1686 onwards, the majority of the silver uncovered was minted on the site at the newly established Royal Norwegian Mint and transported in currency form to Oslo via packhorse or by sledge in the wintertime. An interesting set of coins minted in the 1690s were inscribed with a short poem describing the wealth of silver in the Kongsberg area (and the rather large ego of the Dano-Norwegian ruler):

Det klipperne yder, vor bergmand
udbryder
hvad hytten da gyder, af mynten vi nyder
Saadan Nordens skat Gud giemte
til kong Christian den femte

(Hidden in the hills,
mined by our men,
flowing from the ovens,
the silver is our wealth.
God hid this Nordic treasure
for King Christian the Fifth's pleasure.)

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KIERA TARA O'BRIEN PHOTO

Inside the King's Mine, visitors are guided past beautifully preserved artifacts and machinery.

Located at the center of town, the mint is now a production company that creates coins for circulation, collectors, medals, and other honorary medallions, including the Nobel Peace Prize. The Royal Norwegian Mint Museum in Kongsberg has a brilliant display of minting instruments, coins, and other objects from the earliest days of the mint. A variety of famous pieces were produced at the Royal Norwegian Mint, such as silver coins for the Dutch East India Co. and modern-day Olympic medals.

Fortunately for mineral enthusiasts, not all the silver from Kongsberg ended up in the mint's storehouses. Extraordinary, snaking native silver specimens have given Kongsberg global notoriety as a prime mineral locality. Although "wire silver" formations are not particularly rare in general, occurring in large quantities at a number of ore deposits, they are usually quite short in length. The Kongsberg silvers are favored by seasoned collectors for their impressive size.

These curled, bonsai-style pieces can reach over a meter in length and are sometimes covered in tiny, secondary silver crystals. There are many shapes to choose from: spiny, noodlelike, twisted, or coiled into a "yarn ball." Geologists believe that these diverse shapes were formed when the hot silver ores seeped into small cracks amongst the rocks. The silver probably solidified very quickly afterwards and took on the unpredictable shape of the cracks.

Since the closure of the mines, several hundred wire specimens of varying sizes and designs have come to light in the abandoned mines and their dumps. The largest piece recorded recently consists of a 3.4 kilogram chunk and a long wire specimen stretching about 9½ inches. However, these are rather small when compared to the massive silvers discovered while the mines were still open.

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The most spectacular specimens that were saved from smelting at the Royal Mint over the centuries are housed in the Norwegian Mining Museum in Kongsberg. Security is tight, so you must ask at the museum reception to have the silver room opened for viewing.

IN THE KING'S MINE

Underneath the hills of Kongsberg lies an abandoned network of shafts, tunnels, adits and galleries where generations of miners dug out the silver treasures for the kings of Denmark and Norway. The oldest and largest of the mines at Kongsberg is aptly named the Kongens Mine, or the King's Mine. The opening of the main shaft was located at the spot where the first piece of silver was uncovered by the shepherds and their bull. For many decades, this was the only mine in the area. It took over an hour to climb down the main shaft, which stretched 1,070 meters into the earth at 500 meters below sea level, by ladders.

Inside the galleries of the Kongens Mine are the remains of water-wheel houses, aqueducts, dams, ore mills, inscriptions, and mine roads and trains, as well as evidence of the "firesetting" and "hammering" techniques of mining.

In the earliest stages, the miners used chisels, wedges, sledges and hammers to pound out long, parallel sections of rock to form a proper tunnel shape. They supplemented this system with firesetting, packing wood into crevices and igniting it to heat and crack large flakes of rock off the wall faces. As the German miners from Saxony excavated deeper into the ground, however, they had to change their methods. The Norwegian rocks were much harder than the miners expected, so firesetting became the primary means of excavation, with hammering as its sidekick.

There is an informative (and chilly) safari through the midsections of the Kongens Mine that gives a closer look at the life, challenges and achievements of the miners. After a short train ride 2,300 meters down into the mine, your English-, German- and Norwegian-speaking guide will tell you about the history of the mine, show you the remains of the old mining technology, and give you a peek into the geological belly of the region.

The tour is very accessible overall, with a wooden track laid down for easy walking and only a few stairs to maneuver. If you are feeling up to a fun challenge, you can also arrange to rappel 112 meters down into the mine by contacting the tourist bureau or asking at the Norwegian Mining Museum. They can accommodate everyone from beginners to experts and include a packed lunch for dining deep inside the mineshaft. With over 40,000 visitors every year, this is a top spot for a glimpse into the land down under.

INTO THE FUTURE

In charge of the preservation of Kongsberg's historical and geological heritage, the staff and archives of the local museum are the best sources of information on the region. With five museums under one roof (the Mining Museum, the Mineral Collection, the Industrial Museum, the Mint Museum, and the Ski Museum), this charming institution is full of stunning artifacts, minerals, and informative staff, many of whom have personally interviewed and recorded the stories of former miners from the area.

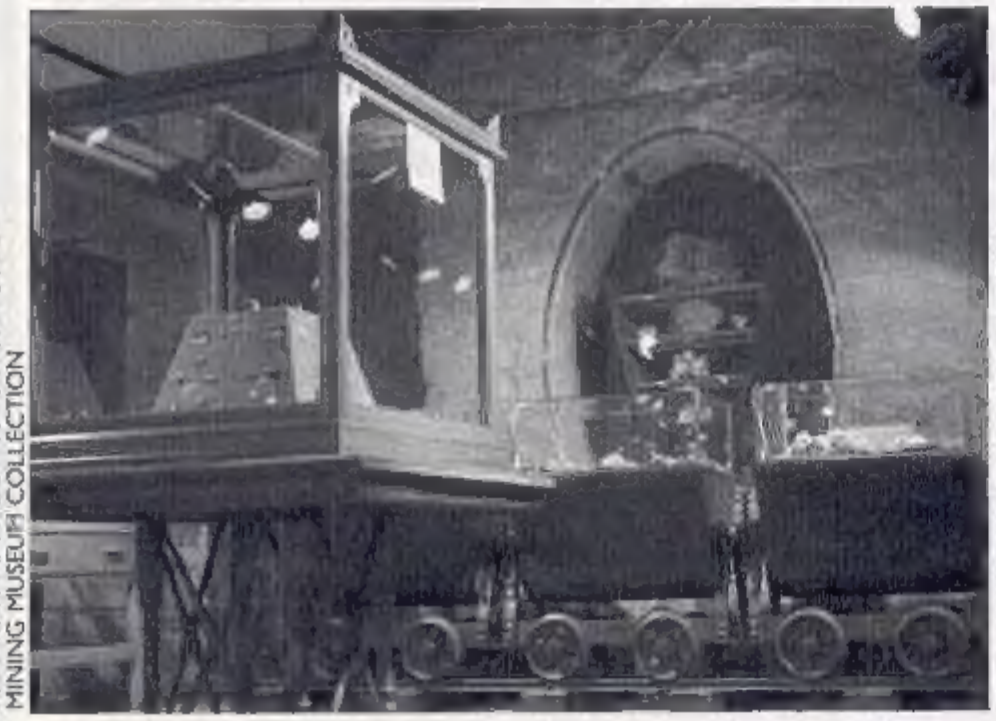
Although the exhibition on minerals and geology in Norway looks a bit outdated, like a step back into 1950, it's informative and full of fabulous pieces from all over the country. The silver room is a treat. Each specimen is set in a red velvet case, but the lighting isn't so great for photos, so bring along a flash. Tours of the mines and old buildings in the area can be organized through the museum.

Although the mines officially closed in 1958, collectors are still picking through the dumps and untouched crevices in the hope of finding a silver treasure. The word on the grapevine for a while was to search the remains next to the old sorting house near the entrance of the Fredriksstoll adit or at the dumps by the Klausstollen adit. From the 1980s, there was a rush to find collectible specimens using metal detectors, which helped to dig up some metal artifacts from the 18th- and 19th-century mining days. Many collectors have even lowered themselves into old shafts to search the abandoned adits.

Today, the central mining area is protected by national law. Collecting activities are restricted from a core 30-square-kilometer area, which covers the most impressive sections of Kongsberg's mining landscape. Despite this, there are a number of mining areas and prospects located outside this protected area, such as the Norske Love and Ringnesgangen.

There are always romantic rumors of rich finds and high prices paid for these discoveries. Some experts even speculate that there is much untapped silver still left in the hills. The costs of modern mining, however, far outweigh the potential profits of finding a large stash of ores. The mining days of Kongsberg are definitely over, but the legacy survives. The delicate wire silvers that poured out of the area are a testament to the artistry of Earth's geological processes and will ensure that Kongsberg is never forgotten.

For more information on visiting Kongsberg, visit www.visitkongsberg.no/index_english.htm.



KIERA TARA O'BRIEN PHOTO/NORWEGIAN MINING MUSEUM COLLECTION

The silver collection at the Mining Museum holds prized specimens from the earliest to the final days of mining in the region.

KIERA TARA O'BRIEN PHOTO/NORWEGIAN MINING MUSEUM COLLECTION

A variety of silvers were collected (and saved from the mints) from the Gottes Hülfe Mine in Kongsberg in 1927.

Pink Tourmaline with Smokey Quartz from Nuristan, Afghanistan

Green Elbaite from Pederneira Mine, Minas Gerais, Brazil